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FEATURES
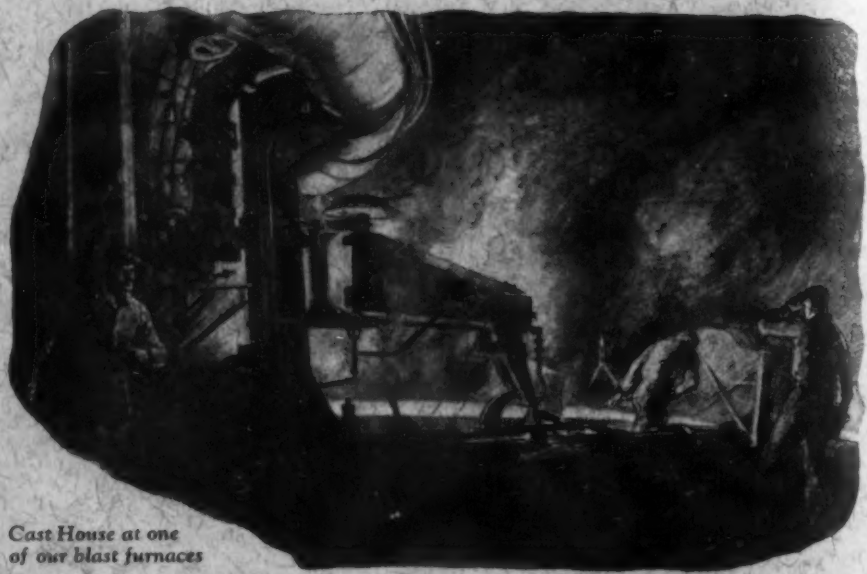
DETERIORATION OF STRUCTURAL STEELS IN THE SYNTHESIS OF AMMONIA

By J. S. Vanick

Abstract

The introduction, in the United States, of nitrogen-fixation by means of the synthesis of ammonia from its gaseous elements hydrogen and nitrogen at a temperature of 932 degrees Fahr. (500 degrees Cent.) and a pressure of 100 atmospheres (1500 pounds per square inch) revealed a lack of information of the effect of the gas mixtures upon metals.

The plain carbon steels quickly showed their susceptibility to deterioration. Early work found some degree of success in a chromium-vanadium steel of the 0.30 per cent carbon, 1.0 per cent chromium, 0.18 per cent vanadium type and this steel was used up to the time the work described was undertaken.

Ten commercial steels, subjected to the working conditions of 932 degrees Fahr. (500 degrees Cent.), 100 atmospheres pressure and 8.3 per cent ammonia, on a laboratory scale, yielded the important results that showed

    (a)   The carbon content should be low

    (b)   Increasing chromium was helpful

    (c)   Tungsten was useful.

A second test was made upon a series of chromium-vanadium steels in which carbon was varied from 0 to 1.15 per cent, chromium from 0 to 14 per cent, and vanadium from 0 to 0.65 per cent. The tests showed that;

    a.   Low carbon was desirable

    b. · Vanadium gave no perceptible improvement

    c.   Chromium in the amount of 2.25 per cent stopped

selective penetration and intergranular fissuring and limited the depth of penetration to a tolerable extent.

An explanation of the mechanism of the deterioration of the steels is advanced. From the facts that oxides are reduced, carbides are decomposed, and nitrides formed in the chromium steels after a slight decarburization has been achieved, an explanation of the mechanism of the deterioration is advanced which regards ammonia as the active corrosive, and the metal as a porous filter which permits an ammonia enrichment to a destructive concentration.

R EACTIONS, such as the direct synthesis of ammonia from hydrogen and nitrogen, which require a combination of high pressures and high temperatures, present unusually severe requirements for structural materials. The synthesis of ammonia is carried out at temperatures of approximately 932 degrees Fahr. (500 degrees Cent.) and at pressures of from 100 to 1000 atmospheres, 1500 to 15,000 pounds per square inch. The combination of such pressures and temperatures, bad enough in itself, is rendered more severe by the corrosion or deterioration of the metal, due to the action of the gases, and the consequences of failures in service of such a system containing an inflammable, explosive gas such as hydrogen, are obviously of a very serious nature. Available data[1] on the physical properties of structural steels at elevated temperatures indicate that the combination of temperature and pressure is serious but can be handled provided corrosion or deterioration of the steels is eliminated.

This paper is concerned with the deterioration, during the synthesis of ammonia, of materials which originally possessed the requisite physical properties. Two previous papers have described the deterioration of steel and wrought iron tubes in hot gaseous ammonia[2], and the deterioration of several metals in hot reducing ammonia gas[3]. Microscopic examination, supplemented by tensile tests before and after exposure, showed that wrought iron, mild steel, copper, nickel and certain alloys all deteriorated rapidly

[1]Bureau of Standards Technological Paper 205.

[2]"Deterioration of Steel and Wrought Iron Tubes in Hot Gaseous Ammonia", by J. S Vanick: TRANSACTIONS, American Society for Steel Treating, Vol. 4, 1923, p. 62.

[3]"Deterioration of Some Metals in Hot Reducing Ammonia Gases", by J. S. Vanick: *Proceedings,* American Society for Testing Materials, Vol. 24-2, 1924, p. 348.

when exposed to gaseous mixtures of nitrogen, hydrogen, and ammonia under the conditions which prevail in either the synthesis or cracking of ammonia.

These results may be summarized as follows: In the synthesis of ammonia at 100 atmospheres pressure and 932 degrees Fahr. (500 degrees Cent.) most of the metals tested were seriously im-
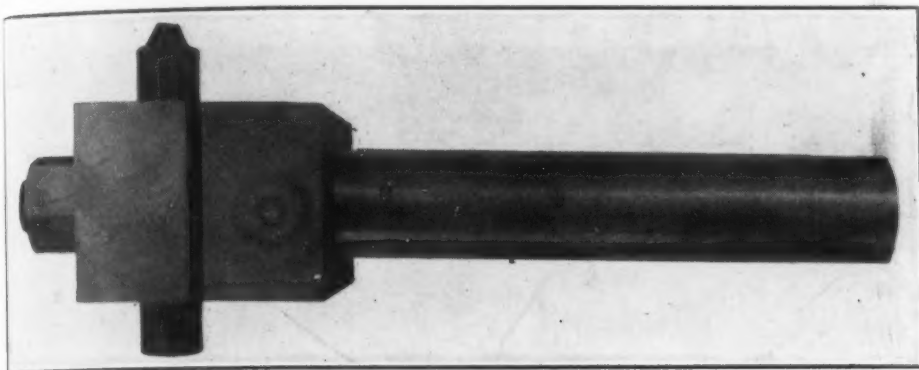
Fig. 1—Test Cylinder.   Approximately One-Fourth Size.

paired through intergranular fissuring. These failures and the one noteworthy case of resistance to attack (shown by a chromium-nickel-silicon-iron alloy) led to the following conclusions:

1. The removal of elements such as carbon or oxygen or their compounds through reaction with hydrogen encourages voiding and fissuring, while the presence of chromium in forming more stable nitrides and retarding the diffusion and penetration of the gas, assists in resisting deterioration.

2. Fissuring is induced by dissolved hydrogen, made soluble by activation from infiltration through the metal or by release from ammonia which is rendered unstable in contact with the catalytic metal surfaces.

3. The more rapid diffusion and effusion of hydrogen, in contrast to the other gases of the mixture, permits an ammonia enrichment to the extent of developing a localized super-equilibrium, with the alternate formation and decomposition of nitrides as a result.

The resistance to deterioration shown by the chromium-nickel-silicon-iron alloy suggested further tests of a number of chromium steels and alloys. Test conditions were chosen to simulate operating conditions in the synthesis of ammonia, namely 932

degrees Fahr. (500 degrees Cent.), 100 atmospheres pressure, and
an ammonia concentration of 8.3 per cent in a gas containing
hydrogen and nitrogen in the proportion of $N_2:3H_2$.   The test
specimens were in the form of cylinders, one for each steel or alloy,
as shown in Fig. 1, with a volume capacity sufficiently large to
accommodate two tensile, two Charpy impact, and two corrosion
specimens of the shape shown in Fig. 2, the specimens having the
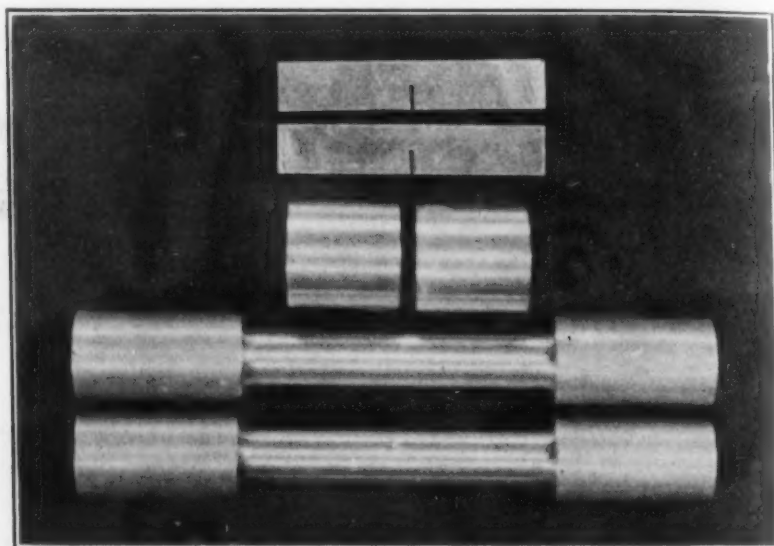
Fig. 2—Tensile, Corrosion and Impact Specimens for Test Cylinder.
Reduced One-Half Size.

same composition and preliminary treatment as the cylinder. These
specimens were exposed on more than one surface to the action of
the hot gases, but were not subjected to the constant stress of 100
atmospheres pressure, as were the test cylinders. Each material
was to be exposed until failure of the cylinder occurred, or until
metal deterioration had progressed to a point where further ex-
posure would yield little additional information.

The cylinders were arranged in a series of five parallel layers,
five cylinders to a layer. The assembly of specimens with electrical
heating coils and outer shell of boiler plate (raised to show the
interior of the assembly) and the complete apparatus, are shown
in Figs. 3 and 4. In addition to the heating coils shown in Fig. 3,
grids at the top and bottom of the assembly provided for the heat-
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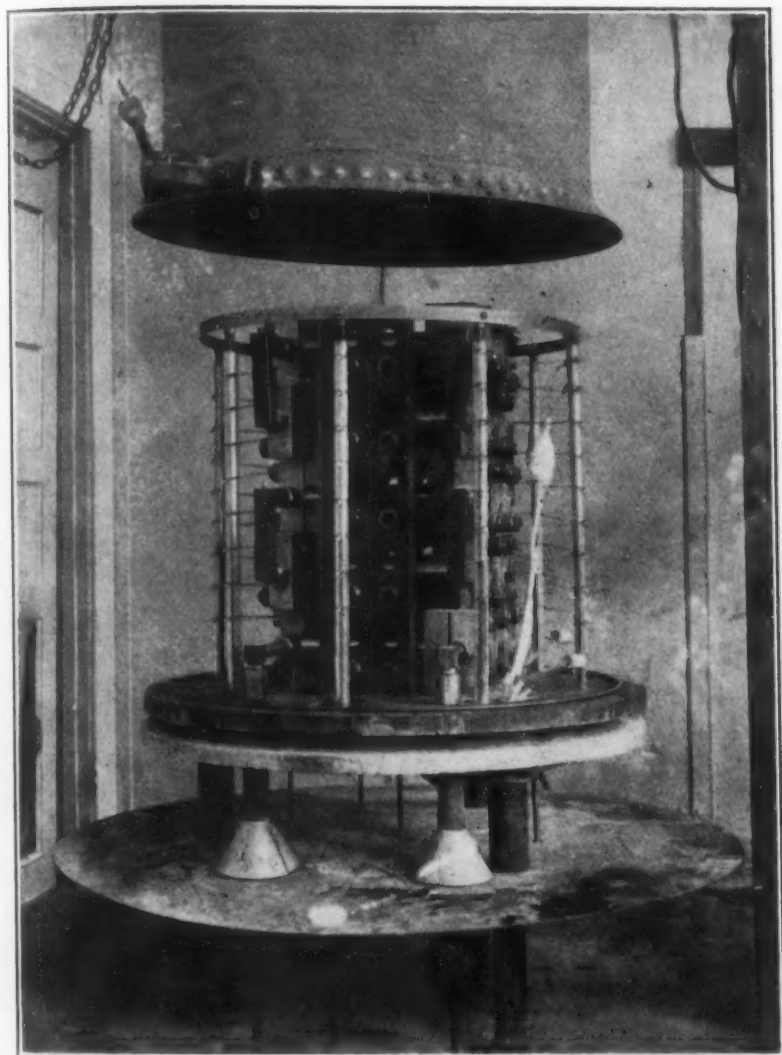
Fig. 3—Assembly of Test Cylinders.

cated. The outer shells were jacketed with magnesia and the heating arrangements were found to give satisfactorily uniform temperature.

The auxiliary furnace, marked A in Fig. 4, consisted of a steel cylinder, capped top and bottom with heavy flanged joints and electrically heated. Duplicate corrosion specimens exposed in this auxiliary furnace were examined periodically to indicate the probable condition of the specimens in the main test bomb.

The requisite concentration of ammonia in the test gases was obtained by first passing the gases under pressure through one of

the two catalyst bombs marked B in Fig. 4. The construction of these catalyst bombs and the generation, purification and compression of the gases has been described in detail elsewhere[4]. The ammonia concentration of the gases was determined at the exit of
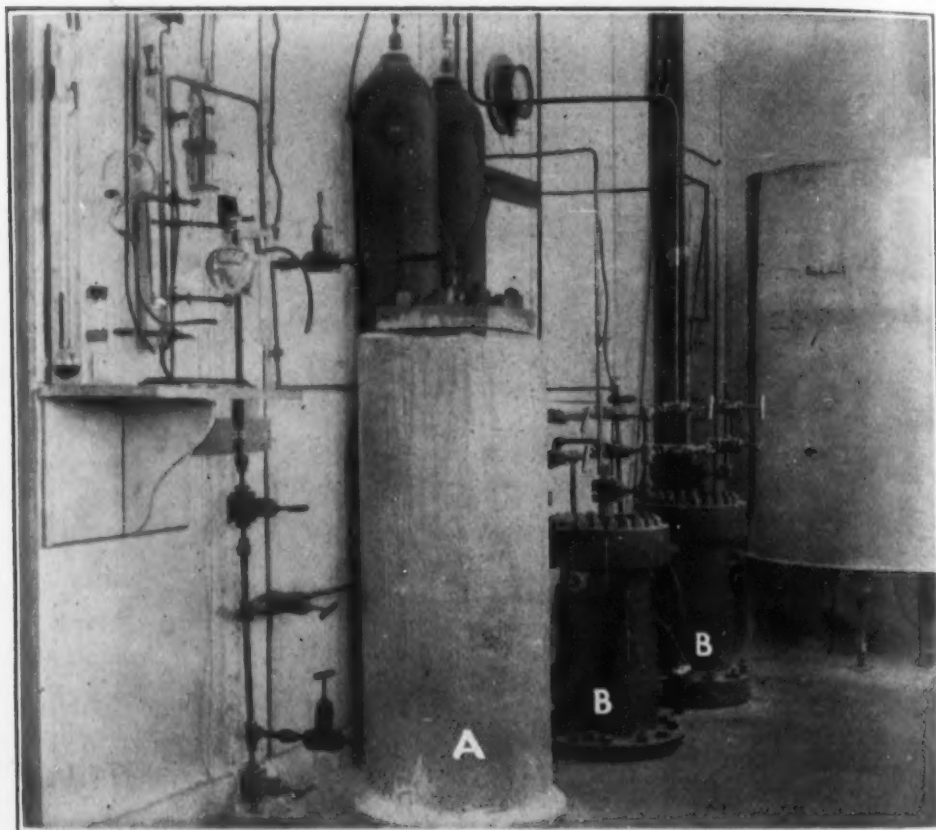
Fig. 4—Complete Test Apparatus.

each catalyst bomb and steel specimen furnace. Apparatus for the sampling and analysis of the gas is shown at the left of Fig. 4. A flow meter indicated the amount of leakage from the high pressure cylinders and connections into the furnace shell and a mercury safety trap provided for the release of the pressure from accumulated leakage or from failure of connections or rupture of a test cylinder. Emergency storage cylinders, whose tops appear in Fig. 4, just back of the corrosion specimen furnace, were used in case of any interruption in the gas supply.

No quantitative data on the ability of commercial steels to withstand the conditions of ammonia synthesis were available, to

[4]R. S. Tour: *Chemical and Metallurgical Engineering*, Vol. 26, 1922, p. 588.

aid in the choice of samples. Some work by Wheeler[5] indicated a decided superiority of a chromium-vanadium steel, but Wheeler's short exposure tests were admittedly "far from quantitative and could merely give a general idea of the effect upon different families of elements." It will be shown later that short exposures may yield inconsistent if not misleading results.

The first set of steel samples listed in Table I might be described as follows:

Steel No.	Description	Usual Purpose
31	Low carbon	Carburizing
32	High carbon	Tools (lathe)
33 and 40	Nickel	Forging-carburizing
35 and 36	Nickel-chromium	Forging
37 and 38	Chromium, high and medium carbon	Bearing-forging
34	Chromium-vanadium	Forging
39	Tungsten-chromium	Forging

All of the steels were given an annealing treatment before being made up into bombs and specimens. They were then exposed to the $N_2 : 3H_2$ gas mixture containing 8.3 per cent ammonia, at

Table I

Composition of 10 Commercial Steels

Serial No.	Specification S. A. E. No.	C	Mn	P	S	Si	Cr	Ni	V	W
31	1020	0.19	0.43	0.008	0.033	0.17	....	....	....	....
32	1095	1.01	0.40	0.007	0.036	0.16	....	....	....	....
33	2330	0.24	0.52	0.008	0.032	0.03	....	3.43	....	....
34	6130	0.30	0.68	0.012	0.024	6.26	0.93	....	0.18	....
35	3335	0.39	0.70	0.011	0.044	0.29	0.84	3.56	....	....
36	3230	0.27	0.59	0.014	0.022	0.18	1.00	1.60	....	....
37	52100	0.93	0.30	0.010	0.014	0.21	1.47	....	....	....
38	5140	0.48	0.79	0.030	0.029	0.23	0.60	....	....	....
39	7260	0.58	0.36	0.064	0.017	....	0.55	0.21	....	1.62
40	2512	0.10	0.31	0.008	0.023	0.31	....	4.87	....	....

100 atmospheres and 932 degrees Fahr. (500 degrees Cent.), for four months. During this period, additional corrosion specimens were removed from the auxiliary furnace at intervals of 1, 2 and 4 months to trace the rate of deterioration. After exposure, tensile test specimens cut from the bomb walls and specimens comprising the charge in the bomb were tested in tension and impact. Macroscopic and microscopic examinations were made of bomb sections and corrosion specimens. Chemical analyses of the affected zones of specimens were made in a few instances to check micro-

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[5]H. E. Wheeler: *Transactions*, American Institute Mining and Metallurgical Engineers, Vol. 67, 1922, p. 257.

Fig. 5a—Progress of Gases Into Nickel-Chromium Steels Nos. 35, 36; Lots I, II and III Represent Exposure of 2 Weeks, 1 Month and 4 Months Respectively. Rectangular Section of Each Corrosion Specimen is Mounted in Solder and Incased in an Iron Ring.
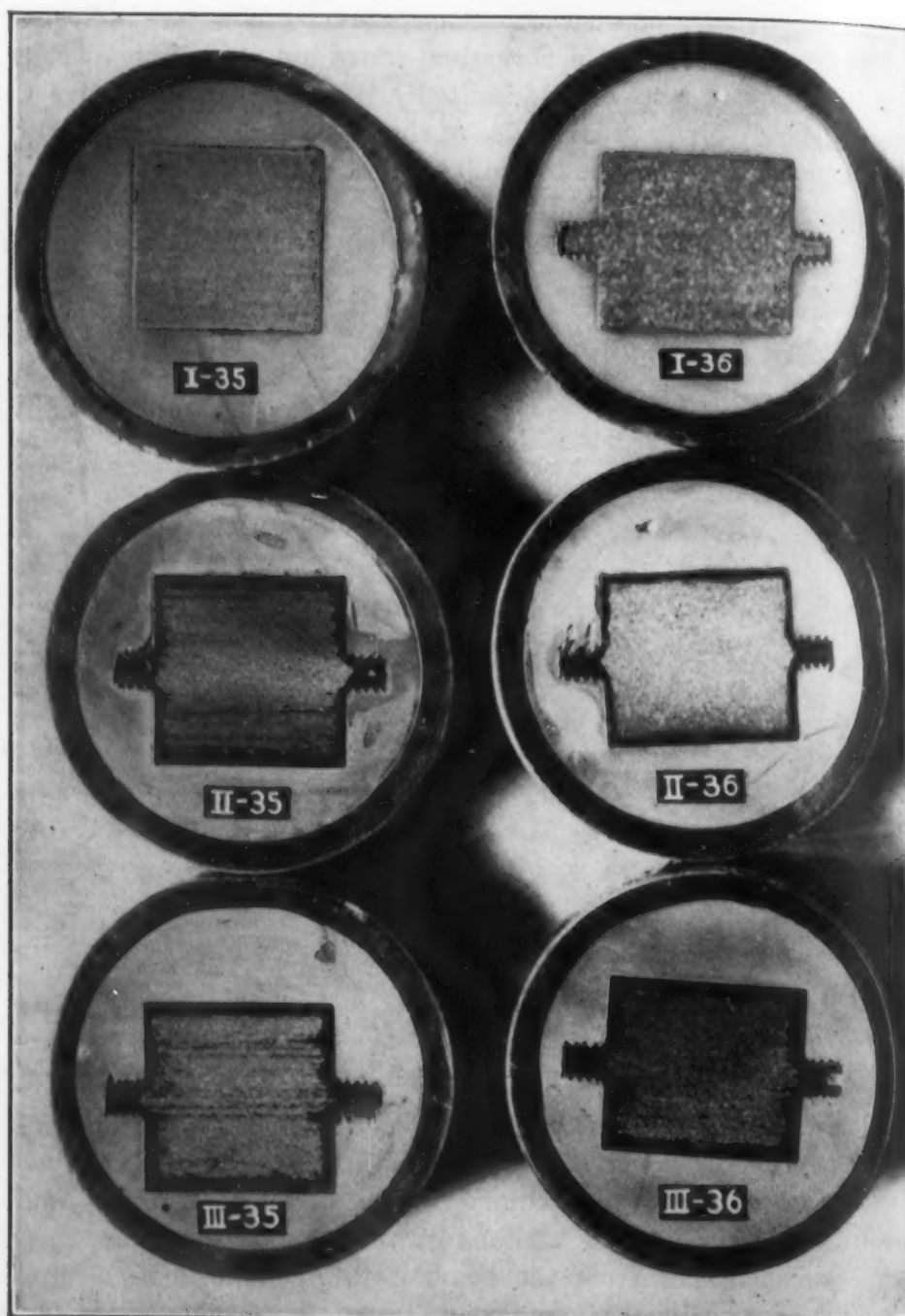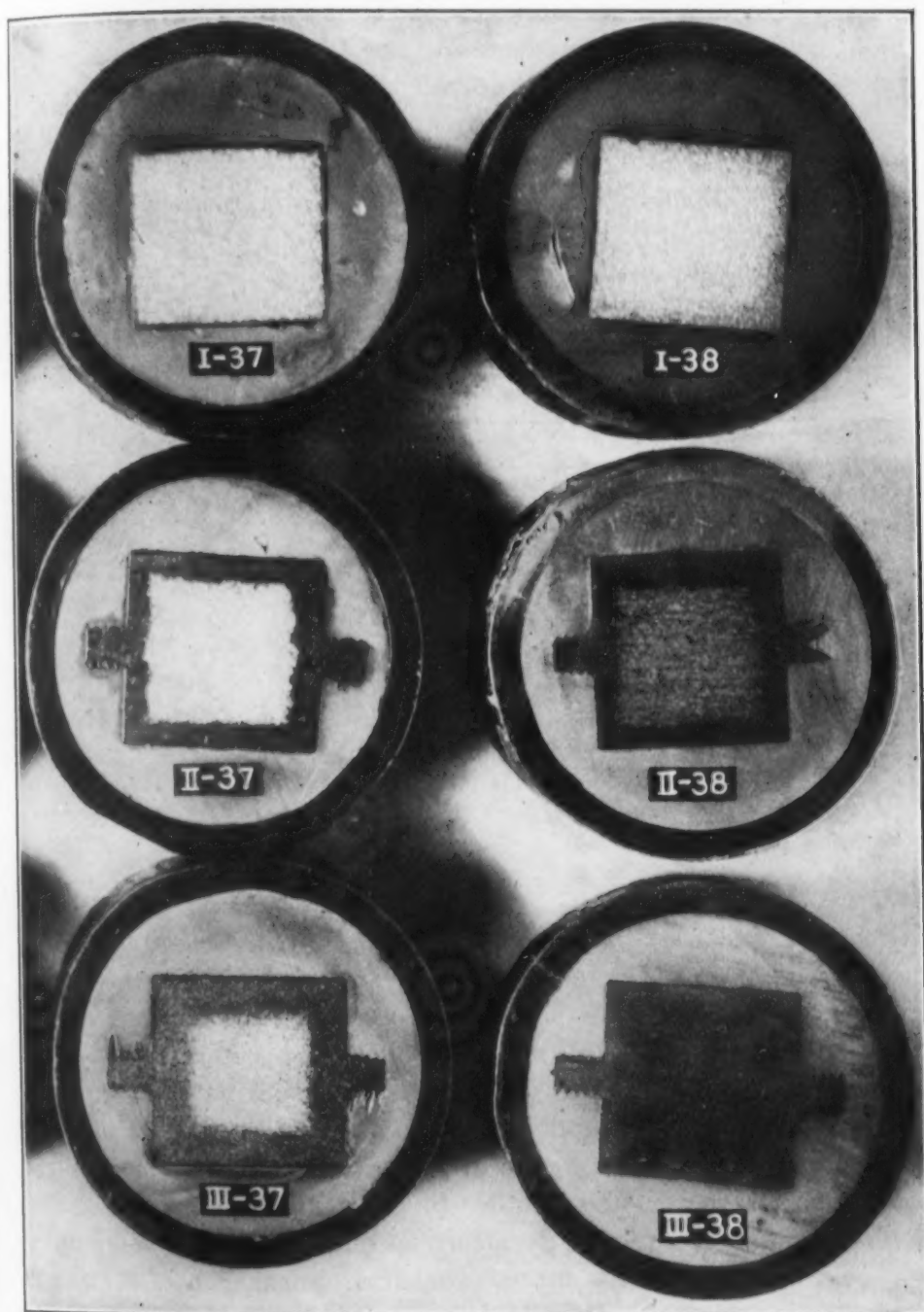
Fig. 5b—Progress of Gases Into Chromium Steels Nos. 37, 38; Lots I, II and III Represent Exposures of 2 Weeks, 1 Month and 4 Months Respectively. Rectangular Section of Each Corrosion Specimen is Mounted in Solder and Incased in an Iron Ring.

scopic observations, and it was soon demonstrated that final judg-
ment could not be rendered on any one test or property alone, but
must be based on a composite of all the information available.

Very little change was shown in any of the samples during the
first two weeks. With longer exposures, fissuring and decarburiza-
tion occurred, usually associated but sometimes independent of each
other, and varying widely in degree or severity. Two types of
penetration were observed, the uniform or concentrically regular

Table II
Effect on Steels of 4 Months' Exposure

Steel No.	Percentage of Original Tensile Strength Retained		Percentage of Thickness of Bomb Wall Affected	Loss of strength Per Unit of Affected Area $\dfrac{100-A}{C}$
	Bomb Walls	Tensile Specimen		
	A	B	C	D
31	105.0	76.0	18.0	....
32	18.7	32.7	73.5	1.105
33	81.0	71.0	49.7	.383
34	86.0	65.7	9.6	1.46
35	69.6	44.4	10.9	3.59
36	84.5	59.4	8.7	1.78
37	47.7	36.9	17.0	3.08
38	65.1	54.3	27.8	1.255
39	96.3	89.8	None	....
40	95.8	91.3	42.9	.098

inward migration and the selective or tendril type of advance, the
latter being harder to detect or evaluate and consequently more dan-
gerous. The origin and progress of fissures along slag spills was
frequently noted. Fig. 5 illustrates typical progress of the attack
with time in the cases of four samples. Decarburization and pene-
tration are evident in the dark rims of the specimens, the affected
area extending clear to the core in some cases. Microscopic fissures
in some cases precede, and in other follow the decarburization. The
tendril type of progressive decarburization is shown by sample 35.

Fig. 6 illustrates the macrostructural appearance of sectioned
bombs after exposure. The shaded areas show the depth of attack
of the more thoroughly penetrated zones and differences between
the high carbon, low carbon, chromium and nickel steels are clearly
evident. However, an estimate of the value of the steels cannot
be based upon the macrostructural evidence alone, on account of
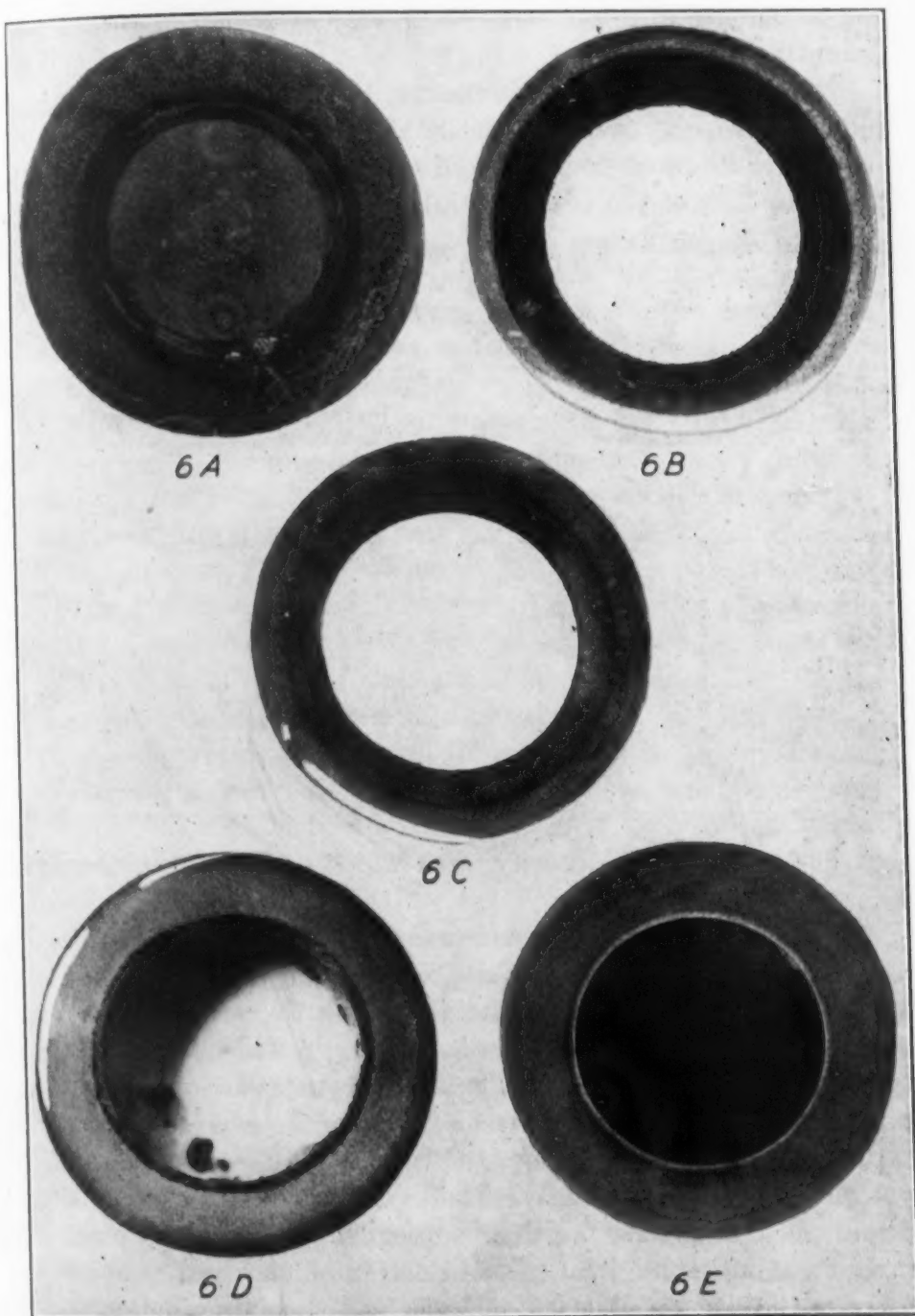
Fig. 6—Circular Sections (with Solder Core) of Test Bombs Showing Penetration, Marked by Blackened Zone, After Four Months' Exposure. (a) Low Carbon Steel 31; (b) High Carbon Steel 32; (c) Nickel Steel 33; (d) High-Carbon Chromium Steel 37; (e) Low-Carbon, Chromium-Vanadium Steel 34.

the occurrence of microscopic fissures which penetrate into the apparently sound areas.

For this first set of specimens, the only reliably measurable physical property was the tensile strength. The brittleness of the specimens, localized fissuring, and possibility of distortion made the determination of the proportional limit and other properties diffi-

Table III
Order of Merit of Steels
(4 months' exposure)

Steel No.	Percentage of Original Tensile Strength Retained		Percentage of Thickness of Bomb Wall Affected	Loss of strength Per Unit of Affected Area $\frac{100-A}{C}$
	Bomb Walls A	Tensile Specimen B	C	D
31	1	3	6	1
32	10	10	10	5
33	6	4	9	4
34	4	5	3	6
35	7	8	4	9
36	5	6	2	8
37	9	9	5	10
38	8	7	7	7
39	2	2	1	2
40	3	1	8	3

cult and reduced the security with which the results might have been interpreted.

In general, a marked decrease in strength and ductility is shown after exposure to the gases. In addition to the loss in ductility, expressed in the values for the elongation and reduction of area, the decreased resistance to impact, represented by the Charpy test data, testifies to the brittleness which exposure produced.

A summary of the results of four months exposure are given in Tables II and III. Column C in these tables is of major importance inasmuch as the resistance of the steel to penetration dominates the reasons for their subsequent adoption. Column C reveals an important item in the relation of chemical composition to resistance to penetration. Neglecting the chromium-tungsten steel No. 39, it is apparent that the greatest resistance to penetration in the chromium steels occurs in the order of an increasing chromium to carbon ratio, regardless of the presence of other elements, viz.:

Steel No.	Cr/C Ratio	Resistance to Penetration
36	3.7	1
34	3.1	2
35	2.15	3
37	1.58	4

This conclusion regarding the importance of the Cr/C ratio is substantiated by later experiments on chromium-vanadium steels.

Column D of the tables is a composite of columns A and C and serves to indicate probable errors in the interpretation of column C, which is based upon microscopic inspection. If an homogeneous material were completely disintegrated or destroyed for the depth of area microscopically observed, and no further, the residual strength per unit area should correspond to the original strength and the value in column D would be unity. Where this factor exceeds unity, as in the low carbon and certain chromium steels, it is evident that the effects of the gas had penetrated the metal beyond the limits of the observed affected area. Conversely, where this factor is less than unity, as in high nickel steel No. 40, there is definite residual strength in the affected area.

A summary of all the data indicates that:

In a comparison of the high and low carbon steels, the net results indicate a lesser deterioration for the low carbon steels, although specimens of both were penetrated to their centers after four months exposure:—

Nickel steels show a distinctive type of selective fissuring, reaching to the core of the specimen in some of the four month exposures:—

Chromium steels within the low range of chromium, studied in this series, also suffer from the treacherous "tendril" form of penetration. It appears that high chromium contents offered greater resistance to penetration, while higher carbon contents permitted greater fissuring and voiding in the penetrated zone:—

Nickel-chromium steels reflect the influence of both elements:—

The tungsten-chromium steel, No. 39, is apparently the least affected of any in this group. Except for inter-granular fissures close to the surface of this specimen, little evidence of attack by the gases was available. This composition is undeniably superior to its companions, notwithstanding an initially high carbon content.

The improvement shown by an ordinary chromium-vanadium

steel over steels previously tested, suggested the possibility of securing still more favorable results from a manipulation of the three principal elements in this steel, namely chromium, vanadium and carbon. In view of the commercial availability of chromium-vanadium steels, it seemed better at this time to follow this lead rather than the one suggested by the decided superiority of the chromium-

Table IV
Compositions of 14 Chromium-Vanadium Steels

Serial No.	C	Mn	P	S	Si	Cr	V
			Chromium	Series			
1	0.37	0.39	0.017	0.022	0.27	0.04	0.19
2	0.29	0.53	0.015	0.011	0.16	0.51	0.28
3	0.30	0.68	0.012	0.024	0.26	0.93	0.18
4	0.31	0.48	0.011	0.011	0.12	2.01	0.34
5	0.33	0.37	0.028	0.013	0.26	7.70	0.18
6	0.42	0.35	0.025	0.009	0.06	14.40	0.18
			Vanadium	Series			
7	0.40	0.53	0.018	0.013	0.18	1.05	0.02
8	0.37	0.52	0.018	0.018	0.20	1.05	0.07
9	0.35	0.37	0.020	0.013	0.20	1.02	0.14
10	0.37	0.55	0.018	0.019	0.18	1.07	0.31
11	0.27	0.34	0.025	0.011	0.29	1.24	0.65
			Carbon	Series			
12	0.16	0.55	0.023	0.023	0.34	1.03	0.20
13	0.58	0.68	0.011	0.017	0.23	0.73	0.18
14	1.16	0.55	0.022	0.018	0.20	1.66	0.29
			"Stainless"	Steels			
27	0.25	0.40	0.020	0.020	0.60	13.50	....
28	0.48	0.09	0.018	0.014	0.43	21.10	0.07

tungsten steel in the experiments just cited. The compositions chosen, as shown in Table IV, represent three series, in each of which one of the three main constituents is varied while the other two are maintained constant. Two steels of the stainless type, No. 27 and 28, were added to the list to expand the chromium series to steels containing 21 per cent of that element. Samples of the commercial 0.30 carbon chromium-vanadium steel used in earlier tests were included with each of these series for comparison.

The samples were double annealed to release strains, as before, and were shaped into bombs and specimens which were exposed to 8.3 per cent ammonia in hydrogen-nitrogen gas at 932 degrees Fahr. (500 degrees Cent.) and 100 atmospheres pressure. The exposure lasted ten months with periodic examination of auxiliary specimens. At the end of ten months, the bombs and specimens were removed and subjected to the routine procedure of tensile, impact, macroscopic and microscopic tests.

The fissured condition of many of the exposed tensile specimens

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again indicated that tensile data, if considered alone, would yield little reliable information. Subsequent microscopic examination verified this expectation, showing that a confused mesh of fine internal fissures accompanied the coarse, readily apparent fissures. Significant exceptions were that chromium-rich steels 4, 5 and 6

Table V
Effect on Steels of 10 Months' Exposure

Steel No.	Percentage of Original Tensile Strength Retained		Percentage of Thickness of Bomb Wall Affected	Loss of strength Per Unit of Affected Area $\dfrac{100-A}{C}$
	Bomb Walls A	Tensile Specimen B	Fissured C	D
Chromium Series				
1	81	86.5	31	0.62
2	80	79.0	38	0.53
3	70	66.0	23	1.32
4	59.5	67.0	13	3.24
5	93	62.0	6	1.27
6	97.5	...	0	...
Vanadium Series				
7	66.5	51.5	30	1.13
8	72.5	61	44	0.62
9	73	44	63	0.42
3	70	66	23	1.32
10	79	44	22–71	0.94–0.29
11	95	71.5	21–84	0.24–0.06
Carbon Series				
12	81	91	34	0.56
3	70	66	23	1.32
13	59	49	53	0.77
14	78	72	42	0.56
Heat Treated Series (6 months' exposure)				
3A	63	55	14	2.64
3B	86	66	14	1.00
3C	80	51	8	2.50
3D	80	63	11	1.80

did not contain fissures and that low carbon steel 12 showed only a few small skin blisters. The better condition of these specimens is attributable to the favorable chromium to carbon ratio in their composition, or for steel 12 to the low carbon content.

The embrittlement of the steels by the action of the hot gases is clearly demonstrated in the ductility values. In most cases, the extension is less than two per cent and in many cases it is practically zero. Table V summarizes the results for this series of speci-

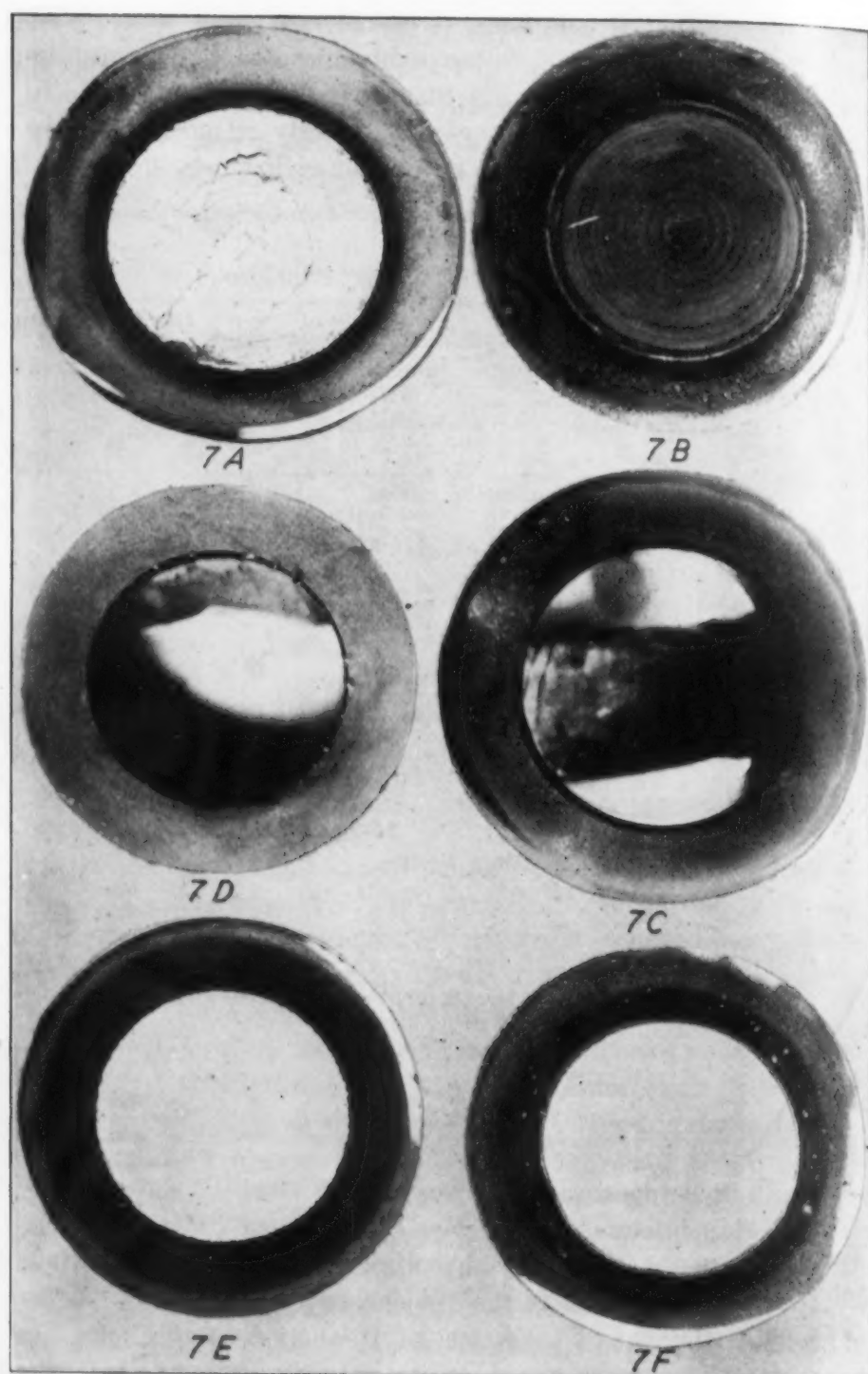Fig. 7—Circular Sections (with Solder Core) of Chromium-Vanadium Steels After Ten Months' Exposure. (a) Chromium Series, Steel No. 1, 0.04 Per Cent Cr; (b) Chromium Series, Steel No. 3, 0.93 Per Cent Cr; (c) Chromium Series, Steel No. 4, 2.01 Per Cent Cr; (d) Chromium Series, Steel No. 6, 14.40 Per Cent Cr; (e) Vanadium Series, Steel No. 11, 0.65 Per Cent V; (f) Carbon Series, Steel No. 13, 0.58 Per Cent C.

mens. It will be noted that consistent values for the percentage of affected area appear only for chromium-rich steels 4, 5 and 6. These values were determined by measuring the depth of the affected zones which appeared in contrast to the apparently sound portions of the deeply etched bomb walls, as shown in Fig. 7. Microscopic examination revealed the presence of fine fissures ex-
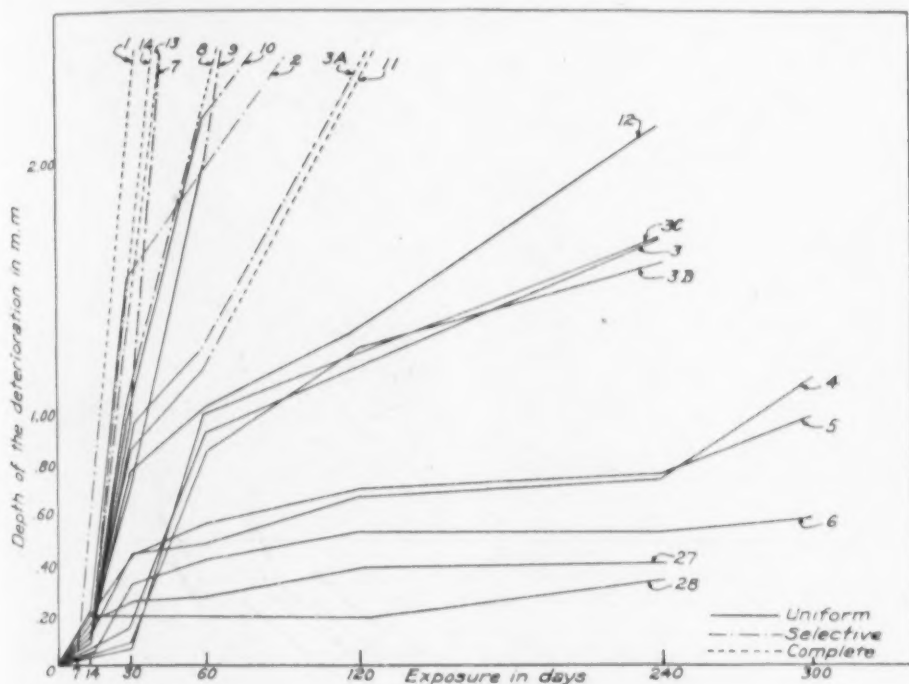
Fig. 8—Exposure in Days, Rate and Type of Deterioration of Chromium-Vanadium Steels.

tending materially beyond this measured depth in all cases except the higher chromium steels. Microscopic fissures could not be found in steels 4, 5 and 6.

Specimens containing more than 7 per cent chromium were colored blue after exposure in contrast to the dull gray of the remaining steels. The blue coloration is attributed to the formation of a nitride of chromium which was dissolved or in solid solution in the skin of the specimens, and which had penetrated in long exposures measurable distances into the steels. The chromium steels showed no appreciable change in their basic structures as a result of the prolonged heating at 932 degrees Fahr. (500 degrees Cent.).

Again in this series, both uniform and selective penetration were noted. The rate and depth of penetration is presented
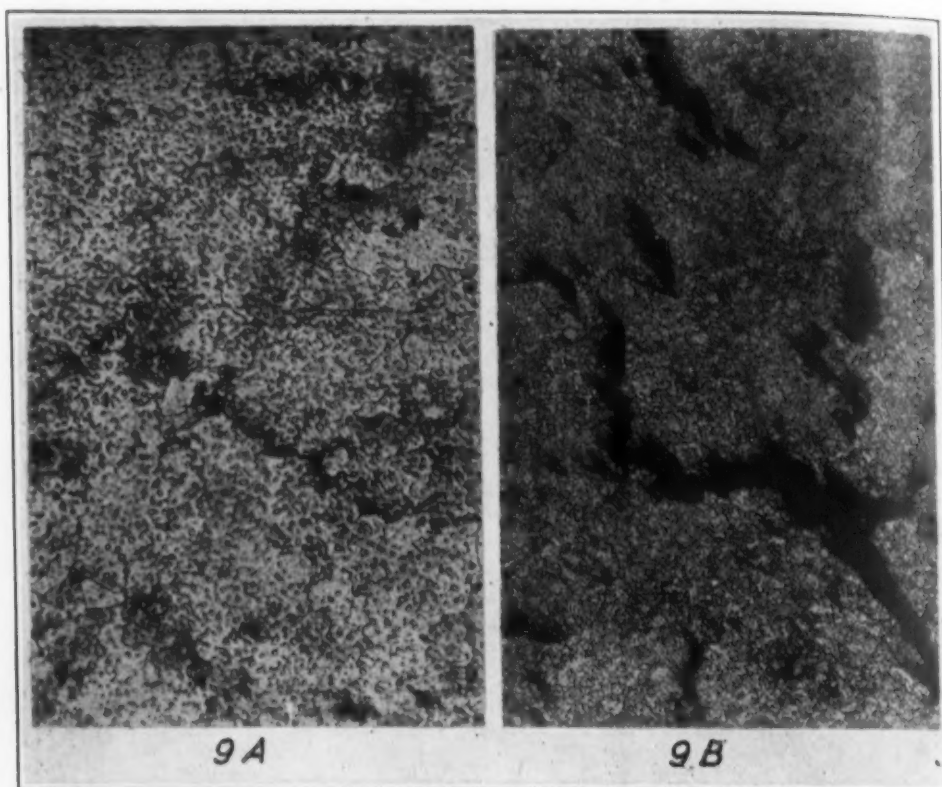
Fig. 9a—High Carbon Steel No. 14, Partly Decarburized and Badly Fissured. 500 x.
Fig. 9b—Medium Carbon Steel No. 13. Through Fissuring and Decarburization. 50 x.

graphically in Fig. 8. The outstanding position of the high chromium steels 4, 5, 6, 27 and 28, is evident.

The data on which Fig. 8 is based include some interesting values for the individual members of the carbon series (No. 3, 12, 13 and 14). These data show that for exposure periods of less than two weeks, the lower carbon steel, No. 12, is more deeply penetrated than the higher carbon No. 13 and 14. However, selective penetration soon appears in the higher carbon samples, and once it has begun, the destruction is rapid and complete. Thus, exposures of short duration are unreliable as they would indicate greater resistance of the high carbon steels, whereas complete data would show the better results for the lower carbon samples, as in Fig. 8. Figs. 9a and 9b illustrate the fissuring and decarburization of high carbon steels, while Fig. 10 illustrates four types of attack observed in various steels.

The positions of the members of the chromium group of steels, No. 1, 2, 3, 4, 5, 6, 27 and 28, in Fig. 8, and the photographs in
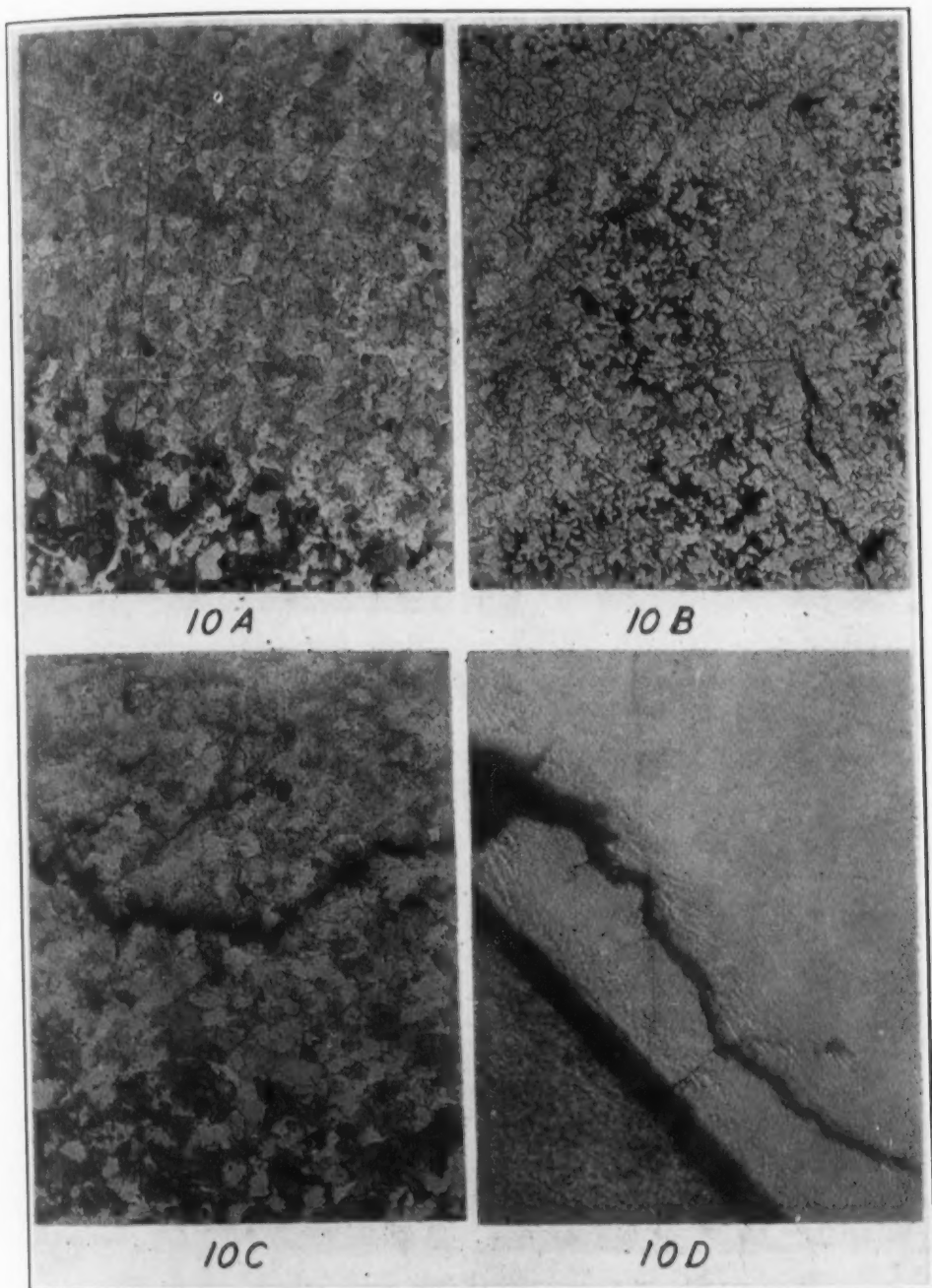
Fig. 10—Four Types of Attack.

(a) A uniform decarbonization is characteristic of steels containing 2 per cent or more chromium. Structure adjoining decarburized zone is but slightly affected. Steel No. 4, Lot IV, 100 x.

(b) A selective penetration marked by fissuring and decarburization, characteristic of low-chromium steels. Steel No. 1, Lot IV, 50 x.

(c) Concentric fissures in the circular section, appear in the better steels subsequent to Lot V. 4 months' exposure. Steel No. 4, 100 x.

(d) In the very high chromium steels, coarse fissures, usually concentric, are always confined to the thin, penetrated zone. Steel No. 27, Lot V, 100 x. All above etched in 2 per cent nitric acid in alcohol.
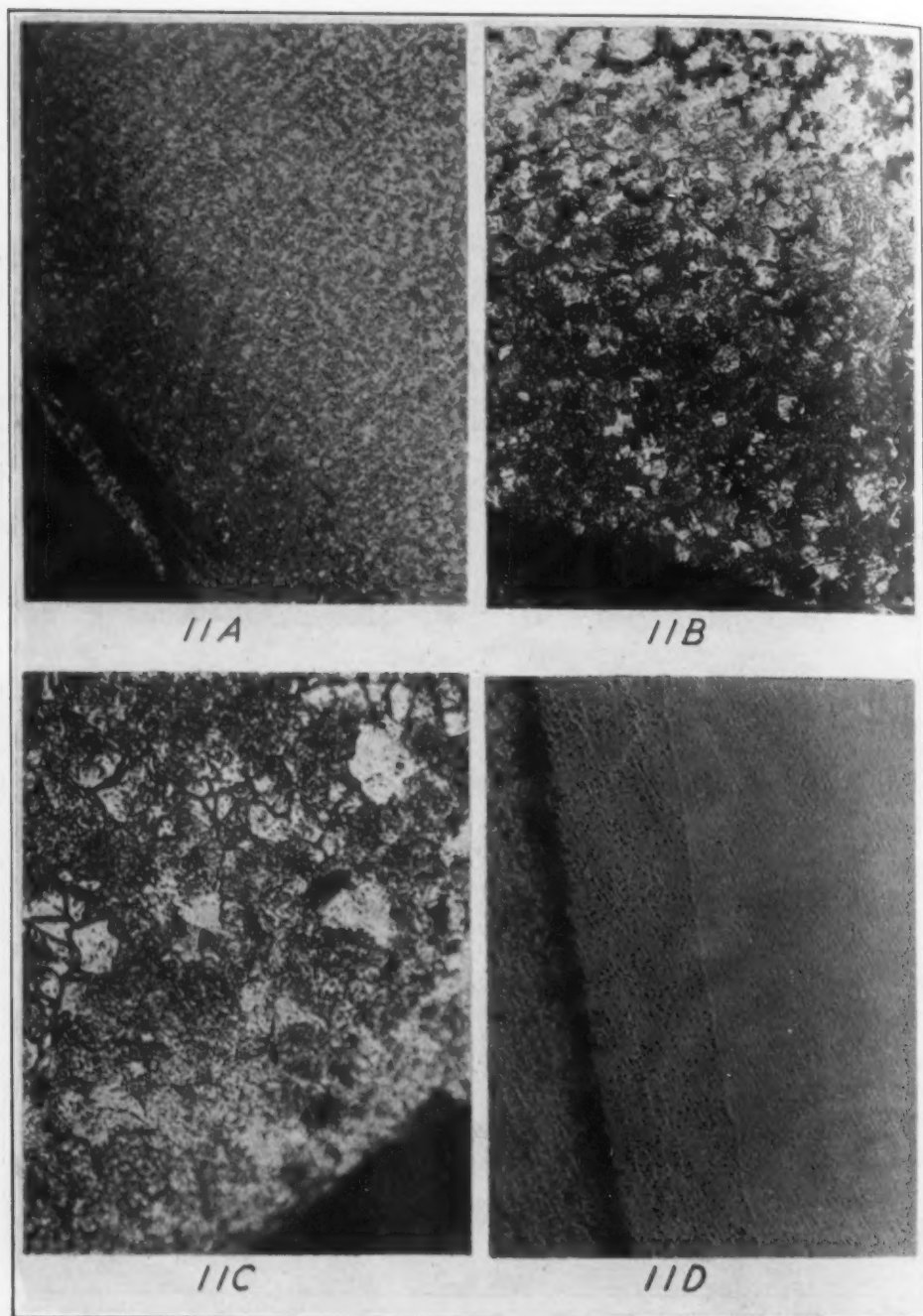
Fig. 11—Deterioration in the Resistant Chromium Steels.
(a)   Darkened surface layer rich in nitrogen is underlain by a decarburized band. Steel No. 4, Lot VI, 50 x.
(b)   Same feature as in 'a', but decarburized band is thinner in the higher chromium steel. Steel No. 5, Lot IV, 100 x.
(c)   Structure of the dark layer. This is apparently a nitride in solid solution which is preserved from rapid decomposition by the higher chromium content. Steel No. 5, Lot III, 500 x.
(d)   Penetrated and nitrified zone is shallow and parallel to the surface in the high chromium steels. Steel No. 28, Lot V, 100 x.
a, b and c etched with 10 per cent nitric acid in alcohol; d, unetched.

Fig. 11 illustrate the influence which the larger quantities of that element exert in retarding the penetration of a 0.30 per cent carbon steel. Two per cent or more of chromium seems to be necessary to retard the rate and to confine the progress of the penetration to a uniform line of advance parallel to the surface contour, i. e., to eliminate the selective, tendril type of progressive deterioration. This feature is perhaps the one of greatest importance in favor of the steel of the 2.0 per cent chromium type. The presence of over 2.0 per cent chromium retards the penetration still more but not in proportion to the magnitude of the chromium increase. For example, steel No. 5, containing 7.7 per cent chromium, is only slightly better than steel No. 4, containing only 2 per cent Cr.

The principal feature marking the superiority of the higher chromium steels is their resistance to selective penetration and to its destructive associates, fissuring and decarburization. A secondary feature which may be of considerable importance is the development of a protective layer in the penetrated zone which probably marks the formation of a solid solution of nitrogen in the chromium-iron matrix.

In connection with the chromium series, the four heat treated specimens of steel No. 3 registered such irregular resistance to penetration, particularly after four months exposure, as to lead to the conclusion that heat treatment of a steel containing less than 2 per cent chromium cannot produce satisfactory resistance.

For the vanadium series, 3, 7, 8, 9, 10 and 11, the data show that a three-fold increase over the ordinary vanadium content of a 1.0 per cent chromium steel failed to improve significantly the resistance of the samples. The steels arrange themselves in order of increasing vanadium content, but all are susceptible to a selective penetration and fissuring and most of them are completely penetrated within sixty days. The improvement noted consists of a refinement in the coarseness of the fissures rather than a retardation of their rate or an obstruction to their depth of advance. Any improvement which the vanadium addition may have contributed was entirely obscured when the chromium content reached or exceeded 2.0 per cent.

DISCUSSION

The deterioration of the steels is a form of corrosion and may be explained by means of a series of chemical reactions with three

factors, temperature, pressure and concentration of reactants, intimately related in the determination of the rate, course and intensity of deterioration. Aside from their influence on gaseous equilibrium conditions, pressure and temperature are significant in the stress exerted on the metal fibers and in increasing the diffusivity of the gases. The reactions proposed for consideration are as follows:

$$(1) \quad FeO + H_2 \rightleftarrows Fe + H_2O$$
$$(2) \quad Fe_3C + H_2 \rightleftarrows CH_4 + Fe$$
$$(3) \quad Fe_3C + H_2O \rightleftarrows CO + Fe + H_2$$
$$(4) \quad NH_3 \rightleftarrows N_2 + 3H_2$$
$$(5) \quad NH_3 + Fe \rightleftarrows Fe_xN_y + H_2$$
$$(6) \quad NH_3b + Fe_xCr_y \rightleftarrows Fe_xCr_yN_z + H_2$$

It is well known that hydrogen will reduce oxides of iron at elevated temperatures. Decarburization occurs under the same conditions, presumably forming hydrocarbons, as in equation 2. The following analyses before and after exposure, confirm microscopic evidence of decarburization:

	C	Mn	P	S	Si	Cr
Steel No. 38—original......	0.48	0.79	0.030	0.027	0.23	0.60
After 4 months exposure....	0.04	0.81	0.032	0.028	0.23	0.57
Cr-V steel—original	0.34		0.010	0.024		
After 6 months............	0.07		0.004	0.026		

A complete chemical explanation of all the deterioration phenomena would involve a cyclic reaction comprising an alternate accumulation and decomposition of ammonia. To conform to this explanation, the metal must act as a porous filter permitting the passage of hydrogen and damming up the ammonia to a super-equilibrium concentration. This ammonia by means of reactions 4, 5 and 6 would intensify and complete the destruction already begun through reactions 1, 2 and 3.

Reaction 4 might be developed by the catalytic effect of the metallic surfaces upon a sub-equilibrium concentration of ammonia to produce simultaneous, compensating synthesis and cracking, or by a local enrichment of ammonia. Such local enrichment, which would promote reaction 5, could develop from the more rapid diffusion and effusion of hydrogen into the metal and by the combination of hydrogen with oxides, carbides, etc. Nitrides so formed would in turn be decomposed and washed out by fresh, incoming, sub-equilibrium gas. Both reactions 4 and 5 would develop atomic or activated hydrogen which would account for the puffing or swelling of

the steels, although some of the observed surface cracking may have been from the mechanical action of escaping products from reactions 1, 2 and 3.

Reaction 6 illustrates the nitrification of high-chromium steels, observed as dark solid solutions in their microstructure. Chemical analysis of thin layers machined from the specimens showed:

Steel No.	Per Cent Combined N_2
5—original	0.016
after 6 months	0.59
6—after 6 months	0.18

In the low-chromium steels the presence of nitrogen as a solid solution was not detectable. The absence of nitrides in the microstructure of most of the steels suggests either that nitrogen or ammonia are not participating in the destruction and deterioration due to hydrogen, or that under the existing conditions chromium forms stable nitrides which obstruct the action of hydrogen while the nitrides of other elements are unstable and decompose as soon as they are formed. No exposures of prolonged duration were made in hydrogen, but, from short exposures and from a survey of the literature, it is doubtful whether deterioration approaching in severity that shown by these steels had ever been observed in steels exposed to molecular hydrogen. It is believed, therefore, that active hydrogen and nitrogen or ammonia are the destructive influences and that their activity is limited in certain cases by the formation of impermeable solid solutions containing chromium nitride.

Physical features obtained from the tests and micro-examinations, support the proposed explanation. The progress of the attack on the steels is marked by:

1. Loss in strength and ductility
2. Decarburization
3. Fissuring

The first evidence of a change in the condition of the steels was observed in an inspection of the 14-day exposure specimens, some of which showed partial decarburization penetrating for an appreciable depth and manifested by a bleaching in tone of the usually dark, pearlitic areas. In resistant steels decarburization proceeds slowly and the line of advance corresponds to the surface contour. In less resistant steels, the initial uniform decarburization usually becomes a selective penetration extending in advance

of the decarburized ring. Since decarburization may be expected in any of the steels, the uniform type is by far preferable to the treacherous, difficult to estimate, selective or tendril type.

Fissuring was usually associated with decarburization and may be described in similar terms, such as continuous or discontinuous; radial, concentric or selective; and so forth. On the other hand, fissures can occur without decarburization since they were clearly developed in practically carbonless iron and in nonferrous alloys.[6] In the steel samples, fissures were equally detectable in decarburized and in undecarburized zones.

The question of whether decarburization and fissuring occur independently of each other therefore remains a matter for speculation in individual cases. At any rate the primary source of fissuring is active hydrogen, with the reaction products of various decarburization or deoxidation reactions as probable auxiliary sources.

The influence of alloying elements, particularly chromium, is apparent in the restricted decarburization[7] and absence of selective fissuring in the higher chromium steels. While some of the resistance to deterioration may be ascribed to the greater stability of the chromium carbides in the hydrogen-rich mixture, the position and extent of the bleached band in the austenitic high-chromium steels indicates that the solid solution of chromium, iron and carbon offers considerable resistance to the diffusion of hydrogen. Therefore, the chromium most directly concerned in obstructing the infiltration of the gas is that portion which is in solid solution in the steel. This suggests the probable superiority of a low carbon, chromium-rich steel. The improvement which might be expected in the vanadium steels as a result of the combination of vanadium with some of the carbon, thereby liberating chromium, was not realized. The vanadium group of steels was severely fissured and decarburized. The nickel steels show a concentric type of fissuring, interesting since it apparently does not appreciably reduce the tangential or longitudinal strength of the test cylinders.

Summary

Practical experience and early experimental work showed that

[6]"Deterioration of Some Metals in Hot Reducing Ammonia Gases", by J. S. Vanick: *Proceedings*, American Society for Testing Materials, Vol. 24-2, 1924, p. 348.

[7]"The Iron-Carbide Equilibrium in Dry Hydrogen at 950° C.", by E. D. Campbell, Wm. L. Fink and John F. Ross: *Journal*, Iron and Steel Institute, Vol. 108-II, p. 173, and by C. R. Austin: *Journal*, Iron and Steel Institute, Vol. 105-I, 1922, p. 93.

plain carbon forging steels were liable to rapid deterioration when exposed to $H_2 : N_2 : NH_3$ gas mixtures as encountered in, and under the conditions of ammonia synthesis. The present work confirmed the earlier findings and also showed that experimental exposures should extend over a period of two months or more, to allow deterioration to develop.

A group of 10 commercially available forging steels, exposed to the hot gases for four months, showed all of the steels susceptible to attack, the extent of deterioration being apparent in differing degrees of decarburization and fissuring. The tensile and ductility properties were lowered, usually the least in the less affected steels. The changes in the test specimen profile, which deterioration inflicts, obscures the true relation in mechanical properties between the corroded product and the original material. More emphasis was placed, therefore, upon the macroscopic and microscopic results. It was found that:—

1. Carbon steels decarburize and fissure readily.

2. Nickel steels were deeply penetrated but showed a high residual strength in spite of the presence of parallel longitudinal fissures aligned in the direction of stress.

3. Chromium steels deteriorated rapidly if high in carbon but were quite resistant if low in carbon.

4. Tungsten and nickel reinforce the deterioration resistance of chromium steels if the latter are low in carbon.

A group of fourteen steels chosen to cover variations of the carbon, chromium and vanadium contents of an ordinary chromium-vanadium steel, within the limits of 0 to 1.20 per cent carbon; 0 to 14.0 per cent chromium; and 0 to 0.65 per cent vanadium showed that:—

1. The carbon content must be low.

2. Two per cent or more chromium is necessary to confine the fissuring and decarburization to a smooth and uniform penetration.

3. A suitable steel would contain at least 2.25 per cent chromium with not more than 0.30 per cent carbon.

4. Larger quantities of chromium improve the resistance further, but not in proportion to the increase in chromium.

5. High chromium and chromium-nickel steels of the stainless type are most resistant but are difficult to forge and machine.

6. Heat treatment is useful to dissolve the alloys in steels

inherently resistant, but adds little or no improvement to partly successful steels.

7. Vanadium adds no appreciable improvement.

The chief features of the attack of the gases upon the steels were represented by:

1. Decarburization.

2. Sharp increase in combined nitrogen principally in the chromium steels.

3. Fissuring, voiding or porosity in the affected zones.

4. Lowered strength and ductility.

Evidence that carbon was eliminated during exposure was secured. Decarburization, fissuring, and the presence of combined nitrogen in some of the steels are accounted for, first by the presence in the gas mixture and the penetration into the steels of molecular hydrogen; second, by the injection of "activated" hydrogen released from catalyzed reactions; third, by the inflation of the crystal lattice by hydrogen "activated" during its infiltration into the steels; fourth, by the more rapid diffusion of hydrogen in the filtration of the gas mixture through the steel, causing localized enrichments of ammonia which accomplish the formation of nitrides, which are, in turn, decomposed. Internal decarburization and the occurrence in a nitride-decomposing gas of nitrogen-rich layers in the chromium steels, are provided for in a cyclic reaction theory of nitride formation and decomposition.

WEAR RESISTANCE OF CUTTING EDGES OF BLANKING DIES AND SHEAR BLADES

By W. J. Merten

Abstract

1. This paper shows and discusses the effect of shearing and blanking of sheets and plates upon the cutting edge of shear blades and die parts when these sheets and plates are covered with hammer or roll scale (Fe_3O_4), or when an intensely hard and abrasive constituent irregularly but profusely scattered or dispersed through it, e. g., iron silicide (FeSi) in silicon sheet.

2. It gives a review of the various methods employed to hinder fragmentation of the hard crystals and imbed them when fractured so as to avoid and neutralize their grinding effect upon the cutting edge.

3. The utility of uniformly hard die parts for burrless blanking and shear cutting is discussed.

4. The importance of die design for obtaining long life of the cutting edge, which is equivalent to the large scale production of a punching free from burrs, is pointed out.

5. Severe deformation of the crystal structure by the use of soft punch parts not evidenced by burr formation is also illustrated.

Introduction

IT is universally recognized that shearing and blanking of sheet steel covered with hammer or roll scale (Fe_3O_4) would dull or wear down the cutting edge of die parts and shear blades and produce a burr earlier than when this scale is absent. Hammer scale Fe_3O_4 is an abrasive material and quite hard as compared with the hardness of low carbon steel. The sesquioxide of iron Fe_3O_4 has a mineral hardness of 5.5 to 6.5 on the Moh scale of hardness. However, since a scale-free material is impractical to be obtained for economical and commercial reasons, the use of heavy, clinging or highly adhesive greases as lubricants has been found to practically neutralize the scoring tendency of the scale. Furthermore, it has been recognized that the imbedding of the crushed crystals of iron oxide scale and the prevention of their pulverization,

spreading and lodging between the cutting edges, is responsible for the improved performance.

Iron silicide crystals (FeSi) in silicon sheet, having a considerably greater abrasive quality than iron scale, reacts similarly on the cutting edges of tools and the tendency to dull the edge is very pronounced if a crushing or pulverizing of crystals takes place and precedes the shearing of the sheet. Evidently any process or method resulting in a splitting of the iron silicide crystals without powdering or severe fragmentation necessarily aids in the retention of the sharp cutting edge and prolongs the life of the die or shear blade.

METHODS TO HINDER EXCESSIVE CRYSTAL FRAGMENTATION.

To bring about splitting of hard crystals of iron oxide (Fe_3O_4) or iron silicide (FeSi) instead of crushing them is accomplished by various methods:

1. By baking on a coating of lubricating enamel.

2. By inserting a layer of paper on top of sheet, i. e. between punch and sheet.

3. By depositing a soft metallic coating such as copper or lead on the surface by dipping sheets into a solution of hot copper sulphate ($CuSO_4$) or lead acetate ($PbC_2H_3O_2$).

Unconsciously, however, all have the same object, namely, to fill the small surface cavities and imperfections and lock or imbed the exposed hard and brittle particles, thereby preventing their fragmentation or powdering and spreading just prior to subjecting the softer ground mass of the sheet to shearing stresses. The more securely such imbedding or locking is, the greater the life and the better the performance of the cutting edge. Deposits of metallic copper or lead obtained from dipping sheets in a solution which precipitates these metals on the sheets should give most satisfactory results. They are, however, not favored on account of the high cost of these materials and the more expensive methods of processes for deposition and application. A striking illustration to the effect of brittle crystals rendered weak and fragile by removing from them their supporting matrix, the soft iron, is the low production and early dulling of the cutting edge from punching pickled sheets. Pickling acid (H_2SO_4) obviously acts only on the iron matrix, the iron silicide being prac-

tically acid-proof. The dissolving of the iron naturally exposes the iron silicide crystals still more and weakens their resistance to crushing stresses and it is practically certain that excessive powdering and spreading took place before actual shearing of the sheet started. Consequently a short production was obtained. See Figs. 1 and 2.

The recognition of these facts explain why fluid lubricants which give merely a wet film are not successful in solving such
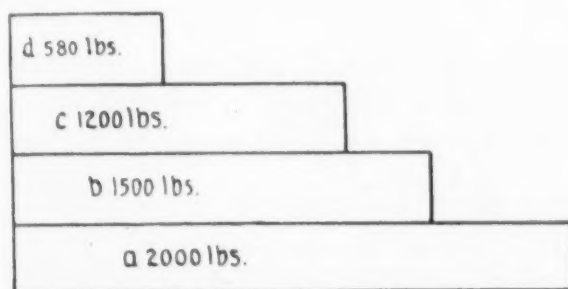
Fig. 1—Diagram Showing Weight of Blanks per Grind when Punching (a) Enameled Mill-Annealed Sheet, (b) Enameled Pickled Sheet, (c) Bare Mill-Annealed Sheet, (d) Bare Pickled Sheet.

problems and their aid is of minor importance. A more substantial and viscous lubricant is needed to imbed and hold the fragments of the split crystal.

Uniformly and Highly Hard Die Parts and Die Design for Burrless Blanking and Shearing Die Steel Characteristics and Properties.

The successful performance of a die and burrless blanking was at one time and not so long ago synonymous with the application of a hard stationary die plate and a soft punch or moving die part, permitting the peening of the edge for refitting without splitting or chipping of the cutting edge. This practice was quite generally accepted as giving best results and long die life. With the quite recent advent of very hard but still tough and highly abrasive resistant alloy tool steels the objections to the fully hard punch and die plate combination have been overcome and close fitting without danger of chipping of the edge can be successfully maintained.

The type of steel now most favorably considered for blank-

ing dies and shear blades is the high-carbon high-chromium type
of tool steel with an approximate chemical composition as follows:

Carbon 2.00-2.25 per cent
Chromium 10.00-12.00 per cent.

This steel will have a scleroscope hardness of 85-95 on oil
quenching from 1800 degrees Fahr. and tempering at 600 degrees
Fahr. It also has nondeforming characteristics.

OUTLINE DIES

The successful application of uniformly hard movable and sta-
tionary die parts, depends to a large degree upon the rigidity of the
punch while blanking. On outline dies where the entire perimeter
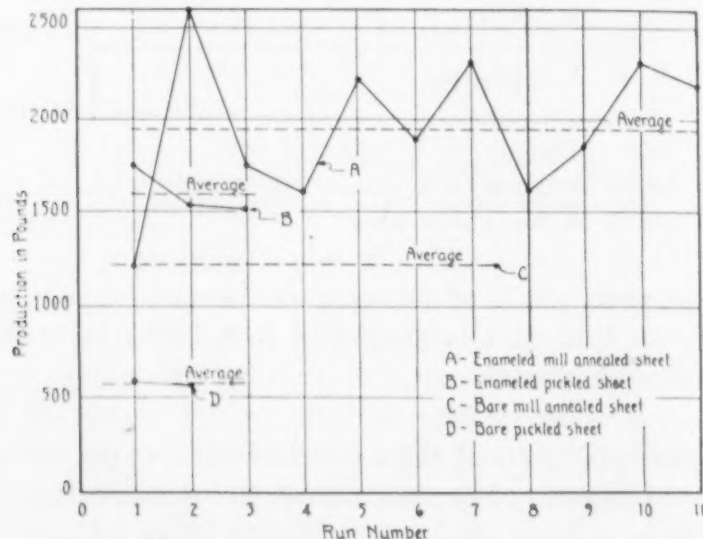
Fig. 2—Curves Showing Weight of Blanks Produced per Grind
when Punching Sheets which have had Different Treatments.

of the punch section is used for cutting edge, the tendency to
produce a side thrust reaction is practically nil, and a hard punch-
hard die plate combination will work out ideally. For dies where
the punch is cutting on one side of the cross section only, the
soft punch is favored. Since no clearance whatsoever can be
allowed between punch and die plate, a tremendous pressure is
exerted upon the cutting side of the punch during blanking. The
grinding effect introduced by a hard punch is greater than from
a soft punch, resulting in a dull edge and producing a burr, after
comparatively few drops. The softer punch being less abrasive

upon the cutting edge of the die plate insures longer life and therefore is favored on dies of this class. An example of a blank from an outline die is shown in Fig. 4. The problem of hard punch and die plate application therefore resolves into one of a die design which arranges the blanking of punchings so that the entire perimeter of the cross section of the punch is cutting. This may be done by double or multiple blanking of parts, giving, however,
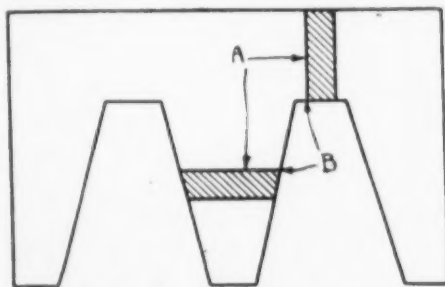
Fig. 3—Sketch Showing "EV" Punchings and the Areas that were Selected for Photographing as Shown in Figs. 4, 5 and 6.

careful consideration to the production of a minimum amount of scrap along with the greater performance, since economy in material may overbalance any gain in die performance.

PLASTIC DEFORMATION OF CRYSTAL STRUCTURE BY USE OF SOFT PUNCH PARTS NOT EVIDENCED BY BURR FORMATION

There is another important consideration aside from producing a burr caused by dull cutting edges of the die, namely, the crushing of the hard crystals and plastic-flow and deformation of the metal held between and sheared by very hard cutting edges as compared with the deformation when held between and sheared by cutting edges, one of which is comparatively soft and the other hard. To investigate this difference, if any, a series of blanks of so-called EV punchings shown in Fig. 3 were selected.

One set was blanked with a newly ground, therefore sharp, edge of soft punch and hard die plate combination die.

Another set was blanked with a newly ground, therefore sharp, edge hard punch and hard die plate combination die.

The third set was blanked with dulled edge of the hard punch and hard die plate die.

Representative punchings from each respective set or lot were then machine-cut as shown in Fig. 3 and the cross section "A"
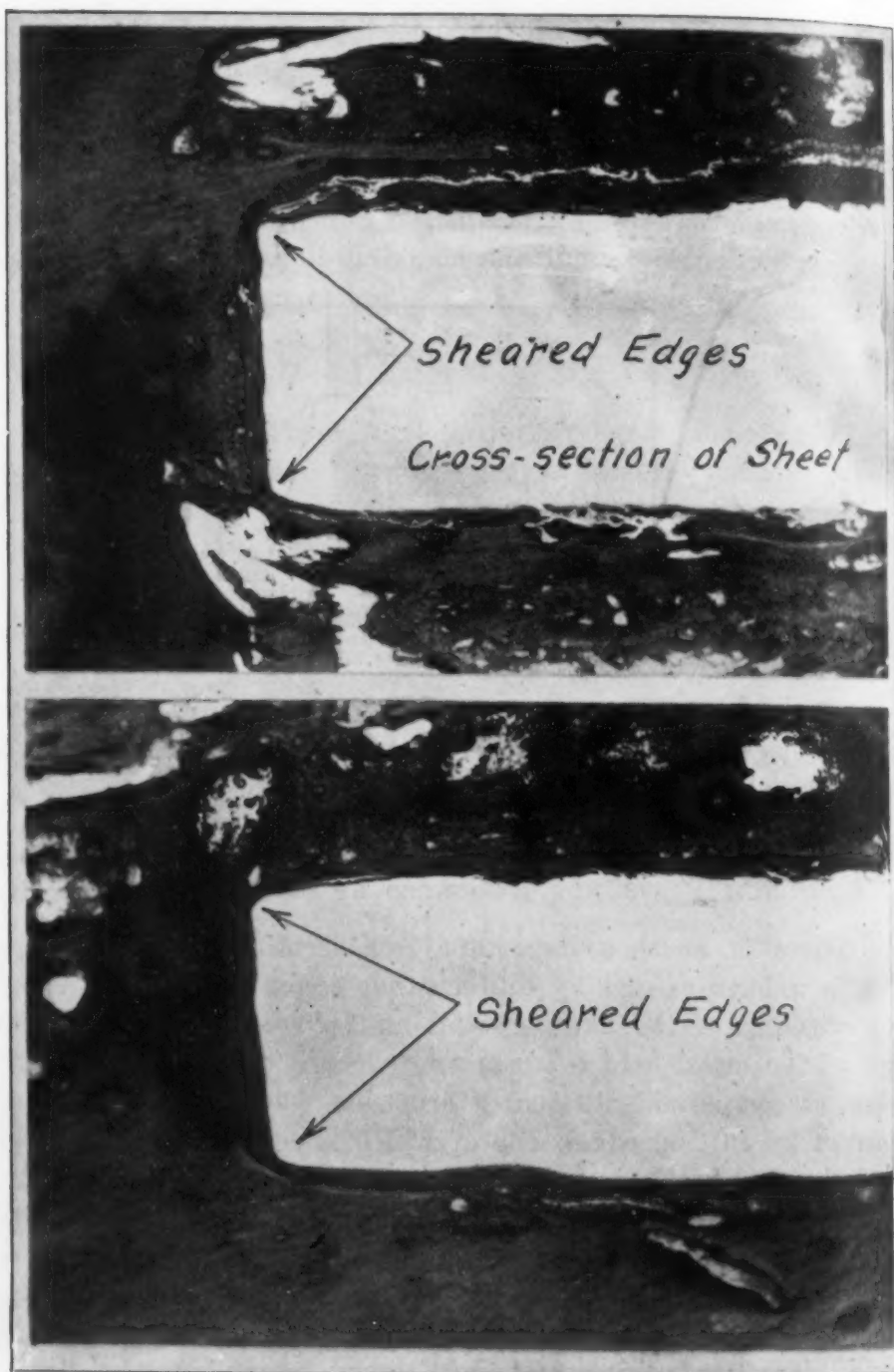
Fig. 4—Photomicrographs of the Cross-section at "B" of a Sheet. The Sheared Edges are Indicated by the Arrows. These Blanks were Produced with a Hard Punch, a Hard Die and a Sharp Edge. Mag. 100 x.
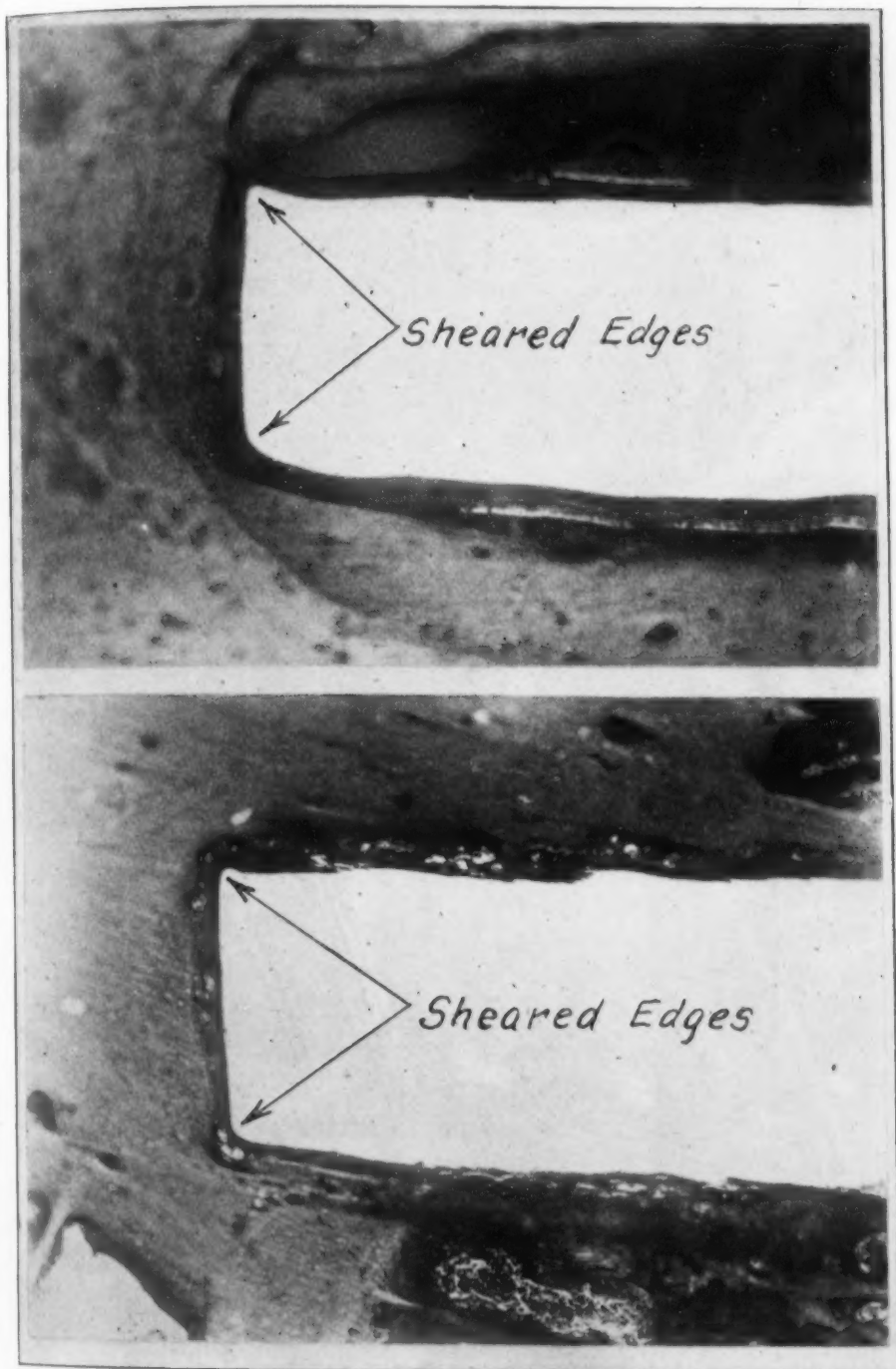
Fig. 5—Photomicrograph of the Cross-section at "B" of a Sheet. The Sheared Edges are Indicated by the Arrows. These Blanks were Produced with a Hard Punch, a Hard Die and a Dull Edge. Mag. 100 x.
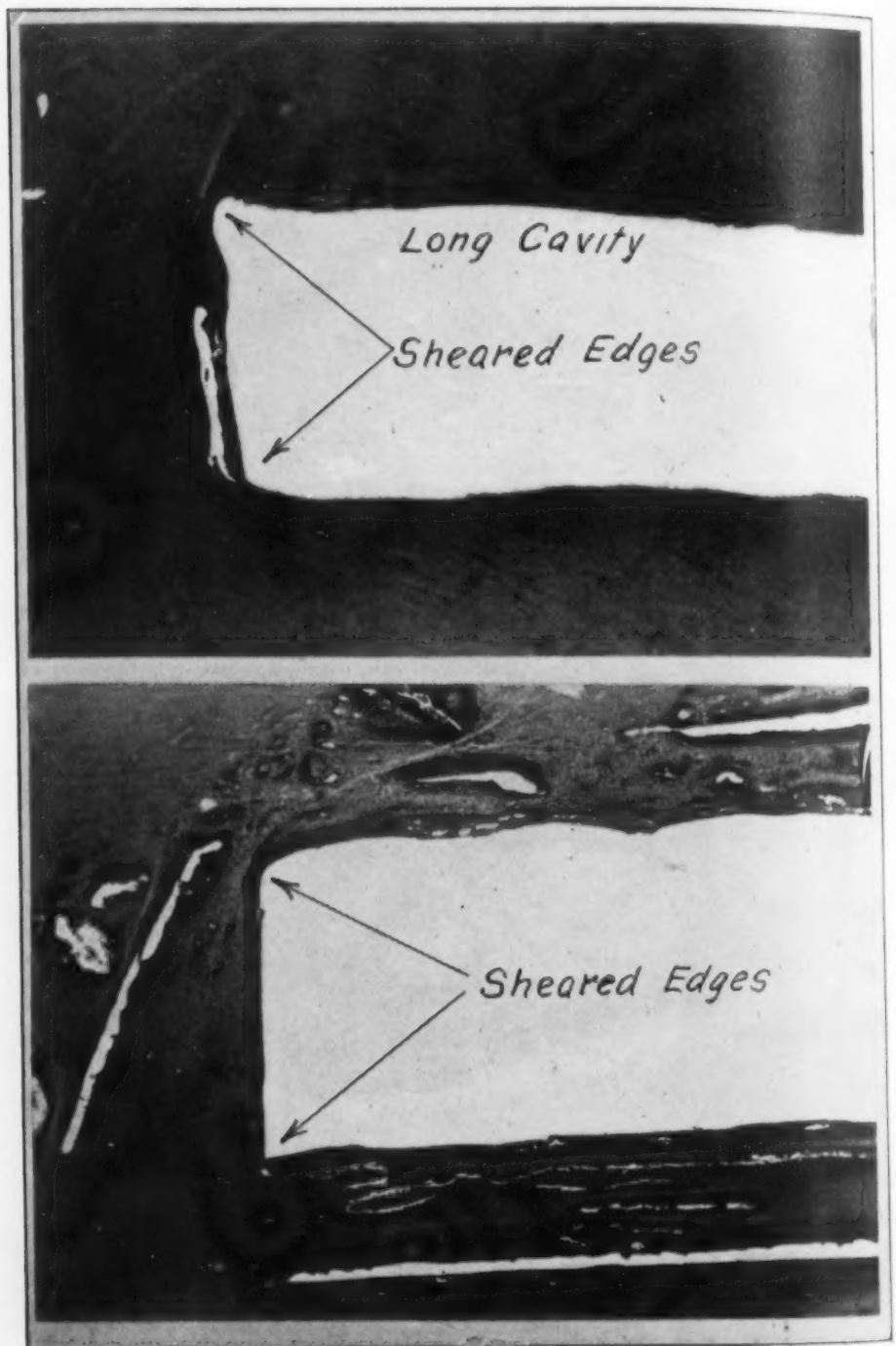
Fig. 6—Photomicrographs of the Cross-section at "B" of a Sheet. The Sheared Edges are Indicated by the Arrows. These Blanks were Produced with a Soft Punch, a Hard Die and a Sharp Edge. Mag. 100 x.

polished for an examination of edge "B" for evidence of degree of plastic deformation of the metal during blanking operation with the different die cutting edge characteristics. Photomicrographs of edge B at 100 diameters magnification were then taken. Figs. 4, 5 and 6.

RESULTS OF INVESTIGATION

It is quite evident from a critical analysis of the photographed sections that the sharp but soft punch and hard die plate combination die produces a considerable dragging effect extending quite a distance into the blank. This type of plastic deformation because of its depth does not show this drag in the form of a burr, Fig. 6, although its deleterious effect upon the electrical and magnetic characteristics may be as bad or worse than the effect of a dulled-edge hard punch and hard die plate combination die where plastic deformation is concentrated and localized near the edge of the blank, being evidenced by a burr. (Fig. 5).

The decidedly advantageous results from a uniformly hard punch and die plate die application in producing the minimum plastic deformation of the sheared section and the immediate adjacent material are plainly and strikingly apparent on comparing Photographs in Fig. 4 with those in Fig. 6.

SUMMARY

A summary of the results of this investigation involving wear resistance of cutting edges of blanking dies and shear blades shows:

1. That the application of highly viscous lubricants aids performance and lessens abrasion or dulling of cutting edges by preventing powdering and spreading of hard and abrasive constituent of sheets.

2. Uniformly and fully hard die parts offer many advantages with regard to quality of blank produced as well as from a quantitative production standpoint. Although it transfers the burden of proper performance in a large degree to the ingenuity of the die designer to design an outline die in which the perimeter of the entire cross section operates during the shearing of the blank, without excessive scrap or over-metal from the sheet.

3. Plastic deformation not evidenced by burr formation is produced by the use of soft punch parts, which deformation may at

the Sheared Edges
h, a Hard Die and

times be more detrimental than a more localized drag resulting in a burr.

CONCLUSIONS

In concluding it should be stated that there are obviously other factors outside of those related to tool maintenance, life of die and quantity production which are to be considered in a final analysis and solution of the problem of increasing the wear resistance of cutting edges of blanking dies, such as—

1. Better space factor in the assembly of the blank in the apparatus or machine.
2. Greater uniformity of grain structure of blank due to less deformation produced during blanking.
3. Lower annealing temperatures and shorter annealing time for restoration of normal crystal structure.

However, the concluding remarks are of a speculative character and purposely injected to stimulate discussion of the paper and encourage further investigative work along a line of activity which certainly is of greatest value to the blanking die manufacturer and stamping and blanking departments of electrical equipment manufacturers.

DISCUSSION

A. H. d'Arcambal: I would like to ask the author of the paper what method was used for hardening these dies.

W. J. Merten: They are packed in charcoal during the heating process.

A. H. d'Arcambal: How long do you allow them to remain at temperature?

W. J. Merten: We give an hour for each half inch of cross section, at 1800 degrees Fahr.

A. H. d'Arcambal: Have you ever noticed the fracture that you get on that type of material?

W. J. Merten: No, fortunately, we have not had any chance to break any of them. They are still running.

A. H. d'Arcambal: The reason I asked is that we have done considerable experimenting with that type of steel and we find that, regardless of how we harden it, it shows quite a coarse fracture as compared with what you would expect from a chromium steel or high speed steel.

R. W. Woodward: I think one of the points that Mr. Merten brought out as influencing the sharpness of the punching, possibly the most important, is the actual design of the press and die. He has not mentioned much about the type of press and equipment that was used, but we have found that the sub-press type of die gives much sharper punching than what he has mentioned; in fact, I think probably a proper sub-press die equipment will

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give much sharper punchings than any he has shown on the screen. May I inquire whether he has used that type at all?

W. J. Merten: The burrs that you saw on the photos of punchings are not very pronounced. If you decrease the burred edge a hundred times you will find very little burr present.

R. W. Woodward: Of course, there is another variable there, in that Mr. Merten is working with silicon steels, which possibly tend to give a greater burr than the straight carbon steels that I am familiar with. I think probably that is an influencing factor too.

W. J. Merten: Mr. Chairman, I anticipated the question on silicon sheet, and I would like to give the gentleman a chance to examine a sample of silicon sheet, which has all the characteristics of a material, of highly abrasive nature, and I will be glad to let him examine the large crystals that are actually present and if he uses a knife or file on it, he will find the knife will not scratch these particles. It is an entirely different matter to cut a soft sheet and then cut a silicon transformer sheet and compare the sheared edges.

E. C. Bain: Mr. Merten, what was the carbon content of this silicon sheet?

W. J. Merten: I think it was 0.002 per cent carbon.

E. C. Bain: You have probably made photomicrographs of that material. May I inquire if you have any with you?

W. J. Merten: No, but they have been made and have been published by others.

E. C. Bain: I supposed of course that you had frequently observed the microstructure and thought it might be rather interesting at this point to show a slide containing some of these silicide crystals which you mention.

T. D. Lynch: I would just like to add to Mr. Merten's paper that the thought already brought out by him that the lubricant in punch die operation is not the same as that thought of as a lubricant on machinery. In this instance something that will hold the die is wanted so that as the die comes down on the sheet to be punched, the action is not like that of a lubricant in a bearing to prevent friction but rather to hold the die in position while the cut is being made. It is also very important to have your machinery rigid and dies so designed that they are firm and the coating of a nature that it will hold the die from slipping and produce a positive cutting of the sheet.

E. C. Bain: Has such a material as "Aquadag" been baked on these sheets prior to stamping with successful results?

W. J. Merten: There have been quite a number of adhesive lubricants used, besides carbonaceous enamel or baking varnish. I personally prefer a metallic coating, but their use runs up the costs, as I indicated.

R. S. Archer: I believe Mr. Merten was good enough to bring along this sample of sheet, largely as the result of a question I asked him in Cleveland a few days ago, at which time I questioned the presence of iron silicide crystals in material of this composition. He said that he had seen such crystals from an eighth to a quarter of an inch in diameter, and that he

would bring some along. I have not been able to recognize in this sample just which crystals are supposed to be this hard constituent. The cross section shows some rather straight cleavages, but it seems to me to be simply the structure of a rather coarse grained iron silicon solid solution rather than of a compound iron silicide. It is my understanding that there is not any free iron silicide in a piece of this composition. If there is any evidence of it I would like to hear it.

E. C. Bain: If the Chair may interpolate a word at this point, the iron silicon diagram has been constructed with an extraordinary amount of care by certain workers in Germany; Faber, Oberhofer and others. Then Phragmen under the direction of Dr. Westgren in Sweden, made a complete study of the entire series with X-rays, and the transformations are completely obliterated with the addition of 1.8 per cent silicon, there is nothing but an alpha iron solution. Silicon seems to be, according to them and others, a material which rapidly stiffens and hardens the ordinary ferrite solid solution, rendering it somewhat brittle at the same time.

I am glad Mr. Archer brought up this question of whether that possibly could be silicide. It may be. I should say offhand there is is an excellent case for the use of X-rays again, because we know precisely what sort of a thing silicide of iron is, and also what the ferrite solution is.

W. J. Merten: I am not particularly interested to argue the point, because I do not know, but what I am really interested in is to demonstrate the brittleness of the material and its abrasive characteristics.

Dr. H. W. Gillett: Stoughton, in his book Engineering Metallurgy, states that FeSi (up to a small proportion) seems to strengthen steel. This is not borne out by Phragmen's work reported to the British Iron and Steel Institute in 1926. My impression in the matter has been entirely expressed by Mr. Archer and Mr. Bain. I doubt very much that iron silicide particles occur in transformer steel.

E. C. Bain: From the diagram as constructed by several competent experimentors it seems impossible to conclude anything else. That is all we are justified in saying at the present time, I think.

A. H. d'Arcambal: I would like to ask Mr. Merten as to what kind of steel he used for dies for punching this material, whether he was using high carbon, high chromium or what?

W. J. Merten: We have used both high speed and oil hardening non-shrinkable steel (1.5 per cent manganese, 0.5 per cent tungsten and 0.5 per cent chromium) but we have not been able to obtain the performance that we expected. The performance obtained from the high carbon, high chromium material has certainly been a credit to this particular grade of material.

R. S. Archer: Having raised this point,—the question about the constitution of those hard crystals,—which, as Mr. Merten points out, is really a minor question from the standpoint of this paper, I would like to express my congratulations on the paper as a whole. I think it is an extremely interesting thing that he has pointed out, and it has aroused my own curiosity as to what might be done in the way of machining by putting on some of these viscous lubricants, such as enamel. I do not know whether anyone has ever

tried it or not, but if the theory of reducing abrasion is correct, it might be of considerable assistance to enamel abrasive materials before cutting them with ordinary cutting tools.

E. C. Bain: Mr. Merten, would you care to tell us how you mounted those thin sheets, laminations, or whatever they were, for photographing? I think some of us would like to know your technique for obtaining the polished cross-section.

W. J. Merten: They were imbedded in a matrix of soft white metal and then polished—just some soft, low-fusing alloy of lead, tin, antimony or bismuth.

F. B. Palmer: I hesitate to ask this question because it is a little off the tenor of the paper, but if we have a minute or two and nothing else to discuss, I would like to inquire a little further along the line of Mr. d'Arcambal's question—that is regarding the relative performance of this particular type of steel in this type of die. I think everybody is interested in this new high chromium alloy, and the question that I have in mind is this: What is the customary method of hardening high speed dies in getting such a comparison as that which the author of the paper just gave? In other words, how do you harden high speed dies that they give only 25 per cent more production than oil hardening tool steel and so much less production than this type of steel?

W. J. Merten: If I understand your question correctly, it is not a matter of producing the number of blanks, but of producing a blank without a burr?

F. B. Palmer: That is what I mean.

W. J. Merten: From a high speed steel heated for development of secondary hardness, the hardness one can expect is about 80 Shore and that hardness does not seem to be sufficient to produce a burrless blank on a material of this kind, particularly on dry cutting. It crushes and spreads the hard crystals over the cutting edge and acts as an abrasive or grinding material. On ordinary sheets or work that does not need to be kept entirely burrless, it will produce tonnage. On transformer sheets to which this particular application refers, high speed steel does not retain its edge.

F. B. Palmer: Have you ever pack-hardened your high speed dies in the neighborhood of 1950 degrees Fahr. for this type of work? In other words, have you ever hardened them substantially the same way that you are hardening carbon high chromium.

W. J. Metren: No, we have not, since to keep packing material and boxes around a tool at temperatures from 2350 to 2400 degrees Fahr. the hardening temperatures of high speed steel is a difficult thing to do.

F. B. Palmer: You will melt high speed steel packed in charcoal at that temperature; high speed steel is usually pack-hardened below 2000 degrees Fahr.

W. J. Merten: We do open fire work on our high speed steels entirely.

E. C. Bain: Mr. Merten, it depends on the inherent nature of the material involved in the mechanism of the process does it not? The mechanics of the thing are studied differently.

HAIR CRACKS IN STEEL RAILS

By J. H. WHITELEY

Abstract

This paper sets forth the various tests made to detect internal flaws or defects in steel rails frequently described as hair cracks. Two methods were employed, the magnetization and treatment with iron dust in kerosene, and the effect of a reagent. The chief features of interest which were revealed by microscopic examination are enumerated.

ALTHOUGH the fact is now well known that steel rails and other rolled material may contain internal flaws frequently described as hair cracks, no complete agreement on their origin has yet been reached. As the result of an examination of a number of single-headed rails containing this defect to a marked extent, the author has put forward in the present paper an explanation which takes into account one or two points that hitherto seem to have been overlooked.

The ingots from which the rails were rolled were made by the basic open-hearth process and the following analysis may be taken as typical of their composition. Ferromanganese and ferro-

	per cent
Carbon	0.62
Silicon	0.20
Phosphorus	0.032
Sulphur	0.044
Manganese	0.79

silicon were used as deoxidizers. Immediately after rolling, the heads had been sorbitized by moving them to and fro in a series of air jets. The rails were thus rapidly cooled from about 1560 to 1110 degrees Fahr., after which further cooling took place normally on the mill floor. On straightening, many of them broke in two and in each case a gray spot was seen to be present in the crystalline fracture. An enlarged photograph of one of these spots is given in Fig. 3. Even in unsorbitized rails they are sometimes found; they vary considerably in size and are usually deep-seated in the head at a distance of about one inch below

the surface. To the unaided eye the characteristic grayness of these areas appears to be due to a finer grain size than that of the surrounding steel.

In order to test for this defect, sections were cut parallel with, and about one inch below, the surface of the rail heads. A fine surface having been prepared on these pieces, the ingenious method devised by Rawdon, consisting of magnetization and treatment with iron dust in kerosene, was first tried. Numerous hair cracks were revealed. A small strip containing one found in this way was cut out and bent; the fracture seen in Fig. 3 occurred along the line of iron dust.

The effect of a reagent which had been found suitable for macro-etching was next tried. It is prepared by dissolving 200 grams of ferric chloride and one gram of cupric chloride in 100 cubic centimeters of hydrochloric acid (sp. gr. 1.16) and 1000 cubic centimeters of water. It etches deeply and the action proceeds without the liberation of any visible amount of hydrogen. In etching, the section is placed in a bath of the reagent and the attack allowed to continue for at least twenty minutes. A finely machined surface should be used. After the first few minutes, it has been found advantageous to remove the specimen, dry the surface, and rub it over with 000 emery paper. The etching is then continued and proceeds uniformly. Fig. 1 shows the effect obtained on a section of one of the defective rails; it is typical of several which were examined. A number of distinct cracks and flaws are revealed lying in different directions. These were not visible to the unaided eye prior to etching. For comparison, the appearance of an etched section from the head of a sound unsorbitized rail of similar composition and size is shown in Fig. 2. Here no unusual feature is present. The dark bands correspond to ferrite ghost lines in a lower carbon steel and are quite normal for this class of material.

A noticeable feature in Fig. 1 is the white area which surrounds each flaw. Oberhoffer[1], appears to have been the first to record this type of defect and he explained it as due to a local segregation of phosphorus and sulphur in the metal. At first sight the white areas might be taken as evidence in that direction since these parts were more resistant to the attack of the reagent. The unlikelihood of segregation occurring in this manner in rolled

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[1] *Stahl und Eisen*, 1913, Sept., p. 1569.
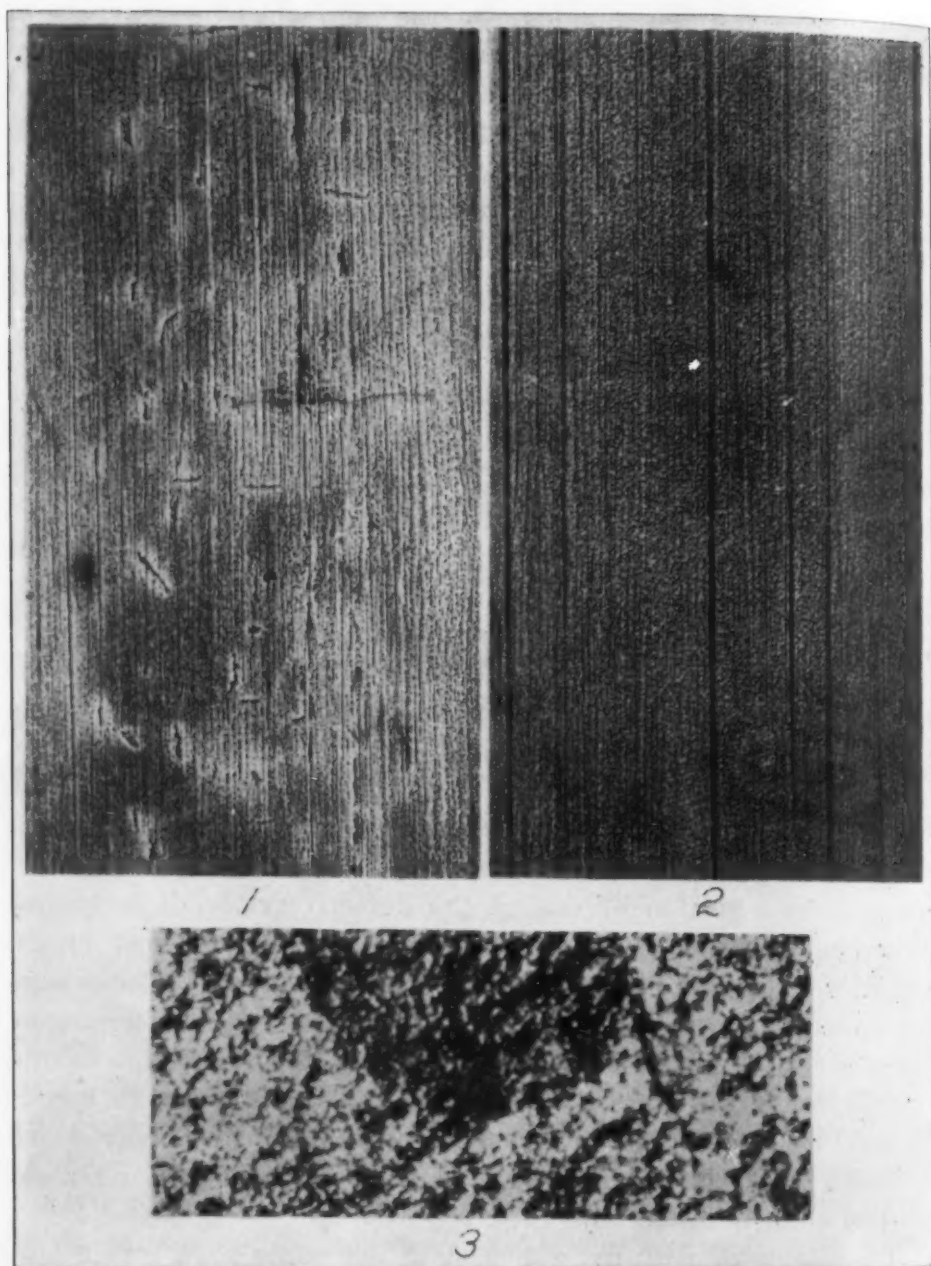
Fig. 1—Full Size Section of Rail Showing Cracks Revealed by Etching. These were not Visible to the Eye before Etching. Fig. 2—Shows a Sound Rail after a Similar Treatment to Fig. 1. Fig. 3—Fractured Surface of Ingot Showing Gray Spot as Described in Text.

material, however, is altogether against this view; moreover, it was found that after the pieces had been heated for a short time at 1560 degrees Fahr. and then air-cooled, these white areas were no longer formed on etching, while the dark ghost lines remained

unaltered. No evidence of any pronounced segregation in any of the samples was found either by direct etching or by sulphur prints.

During the etching process another effect occurred which unfortunately could not be photographed. This was the liberation at various points on the surfaces of a rapid stream of minute gas bubbles. In some cases, the evolution would continue at one point for several minutes before it finally ceased. As the etching proceeded, this liberation of gas was continually starting at fresh places. In etching sound rails this particular feature was never encountered. At first it was thought that some constituent was present which rapidly dissolved in the acid with the evolution of hydrogen, but it was found that an evolution, once it started, could not be stopped by transferring the section to a bath of weak ammonia. Hence it was clear that, at certain points, gas under a considerable pressure was present in the steel. An attempt was made to ascertain approximately the amount of carbon monoxide present in this gas. This was done by allowing a few cubic centimeters to collect in small tubes filled with water and then replacing the latter with acid cupric chloride solution. In each test, the diminution of volume noted, after a strong agitation of the liquid, indicated that at least 50 per cent of carbon monoxide was present.

The chief features of interest disclosed by a careful microscopic examination of sections taken from the rail heads were as follows:

1. Figs. 4 and 5 are typical of the structure seen at the surfaces. The rate of cooling in sorbitizing had evidently been sufficiently slow to allow a separation of the hypoeutectoid ferrite at the grain boundaries. Moreover, under high magnification, it was clear that the "sorbite" was really finely lamellar pearlite, as shown in Fig. 5.

2. The rails contained considerable amounts of sonims which were not evenly distributed. They frequently occurred in patches as illustrated in Fig. 9.

3. After etching lightly with picric acid and then carefully repolishing without the use of a powder, indications of a fine dark deposit at many of the grain boundaries could be seen. An example is given in Fig. 10. Whether the effect was due to the presence of foreign matter or was simply the result of a loose ad-
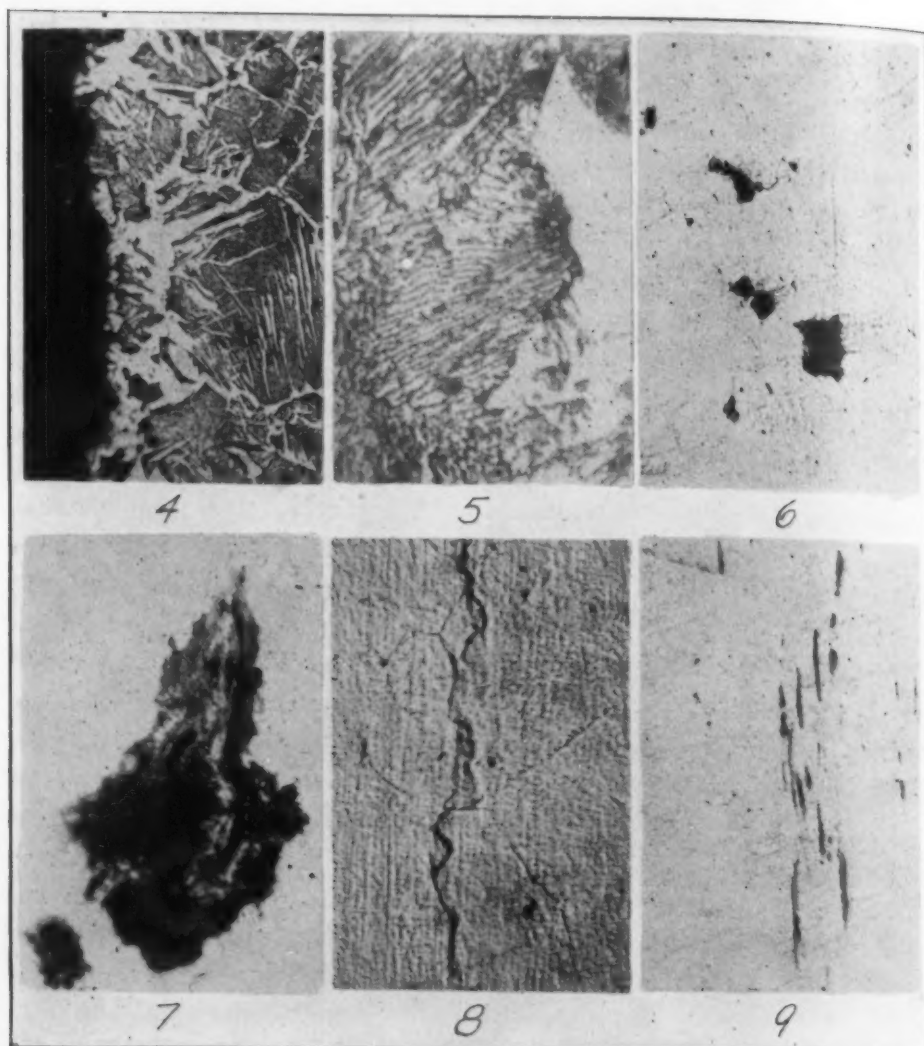
Figs. 4 and 5—Typical Structures of Rail Heads at Surface. The Rate of Cooling has been Sufficiently Slow to Allow a Separation of the Hypoeutectoid Ferrite at the Grain Boundaries. 150X. Figs. 6 and 7—Examples of Porosity of Some of the Specimens Examined. Mag. of Fig. 6, 130X. Mag. of Fig. 7, 850X. Fig. 8—Steel Strip Purposely Cracked to Show the Intercrystalline Nature of the Crack. 160X. Fig. 9—Photomicrograph Showing Unevenly Distributed Sonims. 130X.

hesion could not be definitely ascertained. A small strip of the steel was cracked without breaking in two and the piece then prepared for examination. It was found that there was a distinct tendency for the fracture to travel around the grains. Fig. 8 shows one part of this crack. This result was confirmed when an area containing a distinct hair crack was examined. The rupture, in places, was unquestionably intercrystalline.

4. The evolution of gas in etching from points well away

from any visible flaw obviously indicated that the metal contained minute porosities. A careful examination of many kinds of steel has shown that this defect is more common than is generally realized. Tammann and Bredemeyer[2] have recently done some interesting work in this direction. They subjected specimens immersed in colored water to pressures sufficient to ensure the solution of air and gases contained in the metal. By this means they found that penetration of the water occurred to a considerable depth, thus proving the existence of minute channels and porosities. In the present investigation, evidence of porosity was seen in all the sections examined. Generally the cavities were isolated, but occasionally several were seen together as shown in Fig. 6. Fig. 7 shows one of this group under high magnification.

In examining for porosity, considerable care is needed in preparing the surfaces, otherwise indentations belonging to heavy scratches may remain. These, however, can generally be recognized by their shape and the fact that the metal at the margins shows distortion. It may of course be argued that genuine cavities are due to the falling out of sonims either in polishing or etching. This may sometimes be the case, yet, nevertheless, such looseness is still evidence of discontinuity.

These observations comprise the salient points of interest which appeared during the examination of the rails. It now remains to outline an explanation of the cause of failure based on the facts thus obtained.

The first inference to be drawn is that the steel contained numerous minute cavities filled with gas under a high pressure. Further, it seems reasonable to believe that this pressure was due, in part, to the rapid cooling in sorbitizing, for there would be then less opportunity, than in normal cooling, for the gases to escape by diffusion through the surrounding walls. As a result, severe stresses would develop in the immediate vicinity of the cavities. In this way, local incipient cracks might be formed by rupture along adjacent grain boundaries. Fig. 11 shows such a crack which has apparently traveled from the v-shaped side of a cavity until it reached a sulphide inclusion. It is possible, also, that an effect of this kind would be aided either by looseness or the presence of any foreign matter at the boundaries, such as that shown in Fig. 10. The fact that hair cracks are usually deep-

[2]*Zeitschrift für Anorganische Chemie*, No. 142, 1925.

seated in the heads of the rails and seldom appear in the flange
or web is in agreement with this explanation, for it is obvious
that the greater the distance the gases have to travel in a given
time in order to reach the surface, the less chance will they have
of getting there.   Again, the fact that a retarded cooling tends to
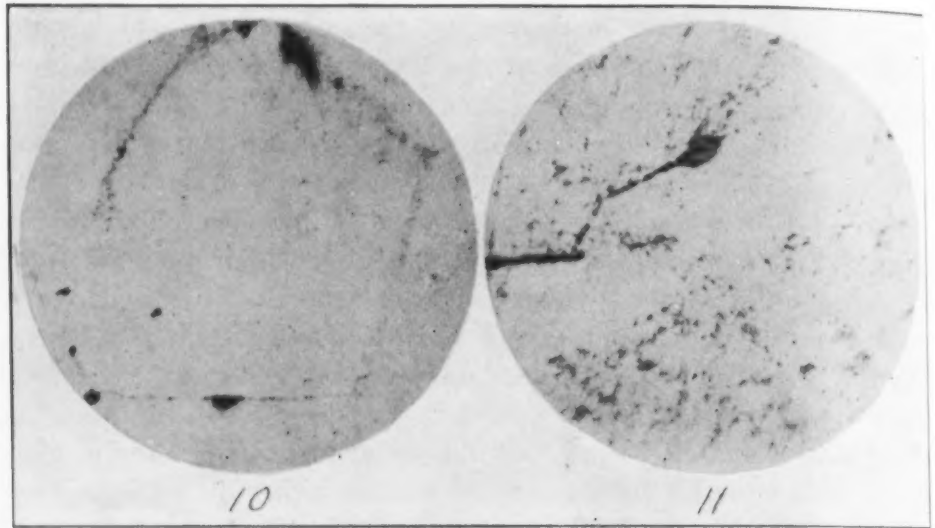
Fig. 10—Specimen Similar to that of Fig. 9 after Etching Lightly with Picric Acid
Followed by Repolishing without the Use of a Powder Shows a Fine Dark Deposit at Many
of the Grain Boundaries.   950X.   Fig. 11—Photomicrograph of a Specimen of Steel wherein
a Crack has Apparently Travelled from the V-shaped Side of a Cavity until it Reached a
Sulphide Inclusion.   950X.

prevent hair cracks, as recently shown by Hultgren[3] in the case
of alloy steels, may also be explained in this way.   More time
is allowed for gases to escape and so relieve the internal stresses
due to gas concentration.

The large proportion of carbon monoxide found in the gases
liberated from the cavities suggests that they are a result of an
interaction between the oxide of iron and the carbon in the steel
during rolling.   A striking illustration of this effect was obtained
from a bloom which blistered badly in the reheating furnace.
The wall of the blister was found to be almost completely de-
carburized and the contained gas gave the following analysis:

	per cent
Nitrogen	5.80
Carbon dioxide	23.0
Carbon monoxide	50.50
Hydrogen	17.20
Methane	3.50

[3]*Journal* of the Iron and Steel Institute, 1925, No. 1, p. 113.

It may of course be contended that the addition of ferro-manganese and ferrosilicon to the ladle would remove all oxide of iron. McCance,[4] however, has recently given evidence, based on thermodynamical considerations, to show that oxide of iron in the metal is not completely reduced by any of these deoxidizers. That the steel had been overoxidized was certainly indicated by the amounts of silicates present. Moreover, it has been found that those conditions of working which tend to keep the oxide content of the bath at a minimum favor the production of sorbitized rails free from hair cracks. For example, the steady removal of the carbon from about 1.0 per cent with a slag not highly ferruginous and the addition of manganese to the bath prior to tapping are both advantageous. These and other facts which might be mentioned all indicate that the trouble is due in the first place to overoxidation of the steel. As a result, carbon monoxide is formed by a subsequent reaction between the oxide and carbon in the solid steel at rolling temperatures and, if time is not allowed for the escape of this entrapped gas as the metal cools, the tendency for hair cracks to develop may be greatly increased.

DISCUSSION

Written Discussion: by F. T. Sisco, metallurgist, Air Corps, Wright Field, Dayton, Ohio.

The type of defect known as the ''hair crack'' or ''hair line'' is so common in steel that the double question of its importance and its cause and prevention is vital. The writer was extremely interested in Mr. Whiteley' discussion of hair lines in rails, especially in his opinion as to the cause of the defect. He would like very much to get Mr. Whiteley's opinion as to whether he considers the hair line to be dangerous. Also if all hair lines are not dangerous how can we distinguish between the ones that are and the ones that are not.

The importance of this question can be judged from one or two instances. There is no part of the airplane engine that is more vital than the crankshaft. The steel used for crankshafts is of the highest grade possible to obtain. In a personal inspection made by J. B. Johnson, chief of the material section, McCook Field, of 100 crankshafts all contained hair lines. It is not going too far to say that, in the case of chromium-nickel steels, if a highly polished section such as a crankshaft is examined carefully, the defect will be found in practically every case.

The writer has had the same experience with ball bearing steels. A rather extensive investigation made on this defect some years ago leads to this conclusion. In a plant making a large tonnage of ball bearing steel

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[4]The Physical Chemistry of Steel-Making. *Transactions*, Faraday Society, 1925, p. 195.

in basic electric furnaces one 2-inch hot-rolled bar from each heat was selected for examination. A piece six feet long was annealed and machined so that the bar diameter tapered from two inches at one to one-half inch at the other. The machined surface was rough polished and examined with a magnifying glass. Hair line seams were found scattered throughout the bar from end to end, and from surface to center. After some experience the question was no longer "if the bar contained hair lines" but "how many hair lines in a unit area examined?"

In other words, all of the steel contained hair lines but some heats contained more than others.

The prevalence of this defect in alloy steels makes it important to know just what effect the hair line may have in accelerating failure by fatigue or vibratory stresses.

The inspector of crankshafts soon finds that if he rejects a crankshaft on account of hair lines he has to reject them all. This is impossible, consequently he would like to know just where to draw the line.

Crankshaft failures in service are comparatively rare. This would seem to indicate that the hair line is not dangerous. But on the other hand, many of the failures that do occur cannot be explained in any other way.

It might be stated that in alloy steels non-metallic inclusions (large enough to be seen by the microscope) are usually not sufficient in amount, or segrated to the point where they can be accused of causing the defect. The logical explanation is gas in the steel.

The writer would appreciate Mr. Whiteley's opinion as to just how dangerous hair lines are and, if possible, a method to differentiate between the ones that are harmless and the ones that are not.

ORAL DISCUSSION

G. A. DORNIN: I did not see the preprint of this paper until I arrived here so this discussion will have to be oral. I have some photographs of split steel ingots. The split ingot shown in Fig. 1 was cast in a regular mold, and you can see about what the interior looks like. Fig. 2 is the same grade of steel cast in an inverted mold with a sink head. This is all rail steel of the following analysis: carbon 0.64 per cent, manganese 0.55 per cent, phosphorus 0.011 per cent, sulphur 0.022 per cent and silicon 0.150 per cent. About 10 ounces of aluminum per ton was added.

Fig. 3 shows two rail ingots, one cast in an ordinary mold and one cast in an inverted mold with a sink head. These show only pipe as far as we can see. There is none of the porous, spongy, blowy condition you can see in the other ingots. I bring these out because most rail steel is what you might term semi-finished steel. The commonest practice that I know of is to run the carbon down to about 7 to 10, where it is easy to check, and tap the heat out to practically a soft heat of steel. Then add enough iron in the ladle to bring the carbon up to the required chemical analysis. Then add enough silicon to bring the silicon up to the required analysis. Most of the silicon, however, will come from the added iron. If it is done that way, in my experi-

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Fig. 1—Typical Undeoxidized Rail Ingot.
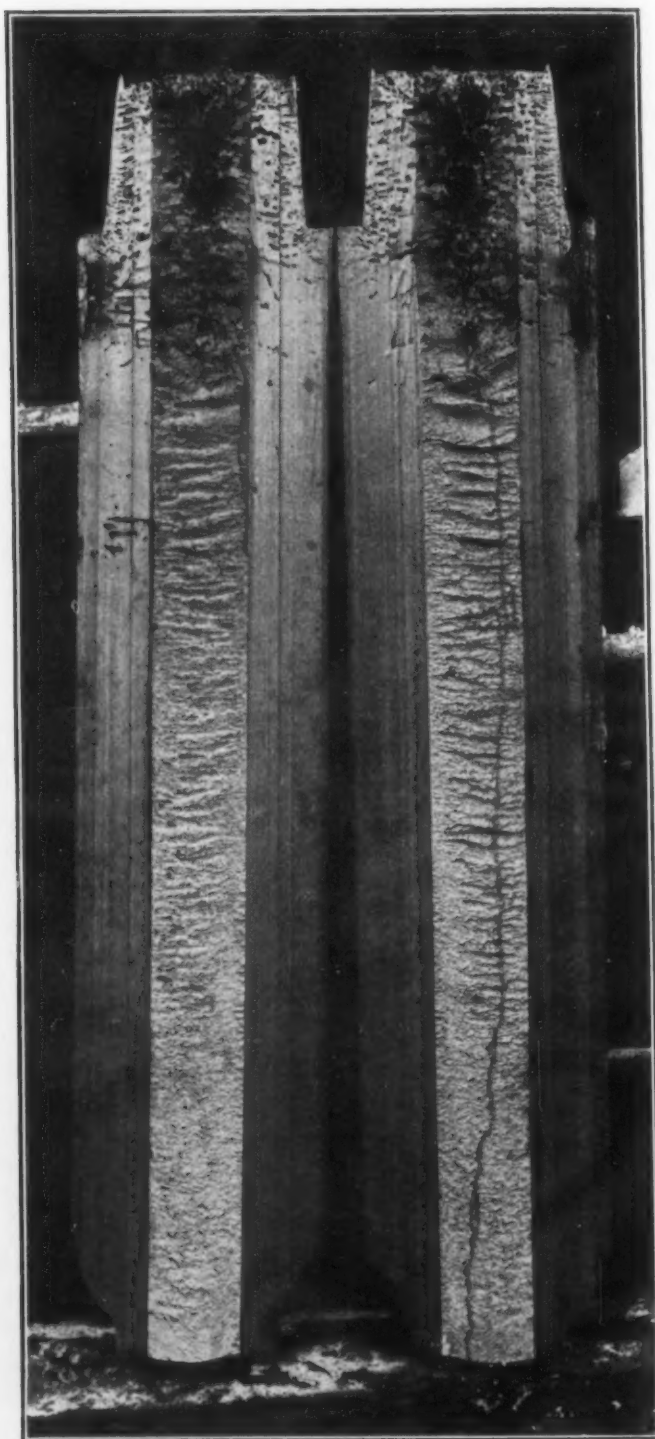
Fig. 2—Big End Up Undeoxidized Rail Ingot.
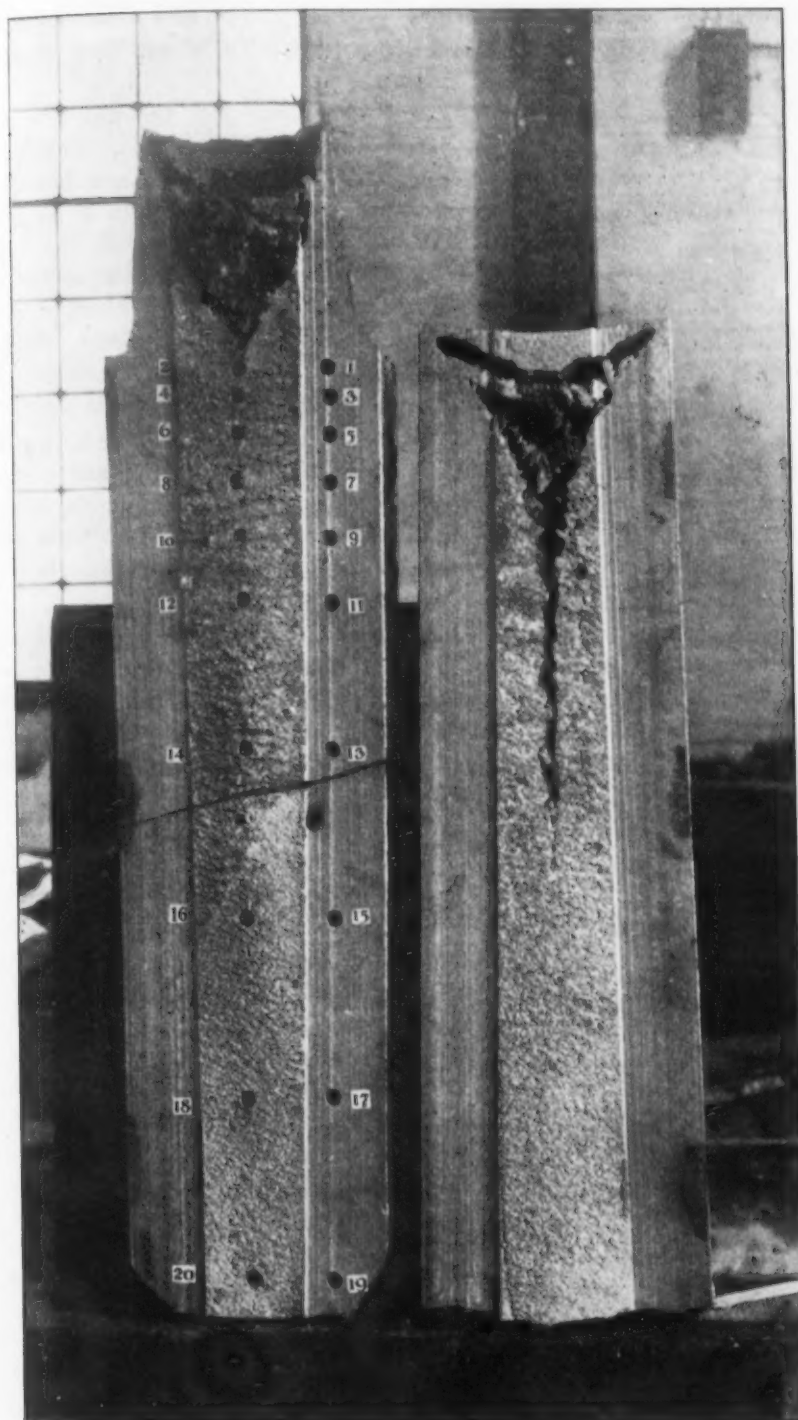
Fig. 3—Big End Up and Big End Down Rail Ingots Cast of Fully Deoxidized Steel.

ence, it does not act as a deoxidizer. A steel poured that way will meet rail specifications, that is, will meet the drop tests. There will be a tremendous saving.

This rail (exhibiting sample) was one made just the way I described, and you can see just about what Mr. Whiteley has described. This rail (exhibiting another sample) was melted as carefully as we know how to melt steel. I mean, the deoxidation was as perfect as we know how to do it today. The silicon was entirely added in the furnace. The hot metal was added in the furnace directly after the silicon and the manganese was added in the furnace. The aluminum was added in the ladle, about two-thirds of a pound per ton, or, in this case I think it was added as silico-aluminum to the equivalent of nearly a pound per ton. I might add here that microscopically or chemically we have been able to find very little aluminum in this steel.

I believe the reason today that rail makers prefer to make ingots the old way rather than the new is that when they deoxidize it and make steel relatively sound, then the pipe cavity shows so plainly. Either the old or the new method steel will pass the drop test, because the drop test tests only the outer fibers and does not test any of this interior area where these hair cracks and something a little worse than hair cracks occur.

EMIL GATHMANN: Mr. Whiteley states that the metal "contained minute porosities." It would be of interest to obtain a more complete description of the finishing of the heat of steel and also of the type of mold in which the ingot was cast, (big end down or big end up) as we have found that these two factors largely control the soundness of the finished product, not only as to position of the shrinkage cavity or pipe, but degree of general cleanness of steel and distribution and degree of porosity.

DR. C. H. HERTY: I would like to make just one statement as to the effect of finishing a heat on the amount of inclusions found in the rail. We made some tests on rail steels where we added the pig iron for recarburizing in the furnace, put the manganese in the furnace, and put th silicon and aluminum in the ladle. We found that if after the addition of the recarburizer the heat lay dead in the furnace that the final rails had considerable amounts of inclusions, whereas if the heat in the furnace after the pig iron was added had a mild boil on it that these inclusions were very small in amount, and an analysis of the finished rails showed that the heats which were killed in the furnace had a very large amount of inclusions, whereas the heats not killed in the furnace but killed in the ladle had very small amounts. The boiling action in the furnace eliminated most of the inclusions formed when the pig iron was added.

J. G. MORROW: I am going to add a little that may be of interest in this connection, though I did not intend to when I came into the meeting. We have been using (I am speaking of the Steel Company of Canada's Works at Hamilton, Ontario) a cascade method of pouring steel from ladle to ingot. The method originated with Sauveur, the equipment, etc. by McKune, the latter invented the McKune port—so it is worth a little thought.

The method consists in pouring the metal from the ladle, into a box or

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A STUDY OF SOME OF THE CAUSES OF FAILURE IN HEAT RESISTING ALLOYS

By Roger Sutton

Abstract

The object of this investigation was to determine the causes for failure in heat resisting alloys; specifically the reasons why nickel-chromium alloy carburizing boxes show so large a variation in their actual life in the furnace. The type of boxes referred to are of approximately 60 nickel, 18 chromium and 15 iron composition.

Introduction

THE process known as "box carburizing" is extensively used at the present time. In this process the parts to be carburized are packed in a container, usually of some heat resisting alloy, along with some carbonaceous material or "carburizing compound", such as charcoal, charred hoofs, and leather, crushed bone, mixtures of barium carbonate, charcoal, etc. A cover is put on the box and the entire load is put into a furnace, heated to 1650 to 1700 degrees Fahr. and held at that temperature for the period of time necessary for the carbon to penetrate the required distance into the piece. This usually requires from 10 to 36 hours.

It was held for many years that in the cementation of iron, solid carbon passed bodily from the packing material into the metal, followed by a slow migration toward the center. Recent investigations, however, have made it evident that the transfer of the carbon from the packing material to the metal is accomplished chiefly, if not altogether, by means of gases liberated or formed during the heat treatment.

Carbon monoxide and volatilized cyanogen compounds are the gases which seem most effective. It may be assumed that the carbon monoxide gives up its carbon to the iron according to the reaction,

$$2\ CO + 3\ Fe \rightarrow Fe_3C + CO_2$$
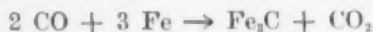
the resulting Fe_3C being dissolved by the austenite much as salt

The author, Roger Sutton, is associated with the Timken-Detroit Axle Co., Detroit.

is dissolved in water and the CO_2 being again reduced to CO on coming in contact with fresh carbon $(CO_2 + C \rightarrow 2\,CO)$.

The particular boxes that interested the author were used in a direct-fired, oil burning furnace with a compound composed principally of charcoal meal and barium carbonate with lesser amounts of sodium carbonate and impurities whose constituents were chiefly sulphides. From this it can be seen that we must deal to a great extent with the effect of the following gases on the alloy: CO, CO_2, Ba_2S, Na_2S, SO_2 (from oxidation of sulphur in fuel) and free oxygen.

MATERIALS TESTED

For this work, five boxes of different furnace life were chosen. Care was also taken to select boxes showing different apparent reasons for failure, as in Figs. 1 and 2, which show a large crack, evidently due to shrinkage, some blisters just forming, and the large abscesses which have eaten in some places through the entire wall of the box.

Table I
Chemical Analysis of Five Boxes Together With the Life in Furnace Hours of Each One

(The guaranteed life of these pots is from 2700 to 3000 hours)

Box	C	Ni	Cr	Fe	Al	Mn	Si	Life
I	0.98	60.61	16.39	10.46	0.942	1.15	2.62	At least 7500 hrs.—good as new.
II	1.09	47.93	22.58	13.88	2.30	1.40	4.77	727 hrs.
III	1.06	58.57	20.71	9.30	2.15	1.20	3.58	Less than 500 hrs.
IV	1.09	56.71	13.81	21.19	1.09	0.97	1.50	1549 hrs.
V	1.04	60.04	18.70	15.81	...	0.88	1.28	About 75 hours.

A consideration of the analysis, Table I, shows that the carbon content has little, if anything, to do with the problem, as it is practically uniform in the five samples taken. The nickel is found to vary only in box No. II and this may be discarded as a possibility of failure due to the fact that there was no tendency toward scaling or the formation of abscesses; this box being apparently as good as new. It seemingly failed due to a combination of thin walls and cooling shrinkage. The effect of the chromium may be discarded inasmuch as boxes No. I and V show nearly equal percentages of that element and they are, respectively, the best and the poorest of

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Fig. 1—Photograph of Box Showing Large Cracks Evidently Due to Shrinkage. The White Spots are Due to Fireclay and are Not Defects in the Box.

Fig. 2—Photograph of Box Showing Blisters and Abscesses Which Have Eaten Through in Some Places.

all those examined. There is slight possibility that the iron plays any part in the life of these boxes, since No. III, a very poor box, is lower in iron than No. I; while No. V, also very poor, is of a higher ferrous content.

Aluminum seemingly plays a more important part than the preceding elements. The four boxes containing aluminum were more or less free from heavy scale; while box No. V, with no aluminum, showed a heavy and extremely detrimental scale after only a very few hours usage. Fig. 3 shows the manner in which the inclusions occur in the pots. Fig. 4 shows the scaling effect in box No. V. These inclusions seem to be the basis of the abscesses which

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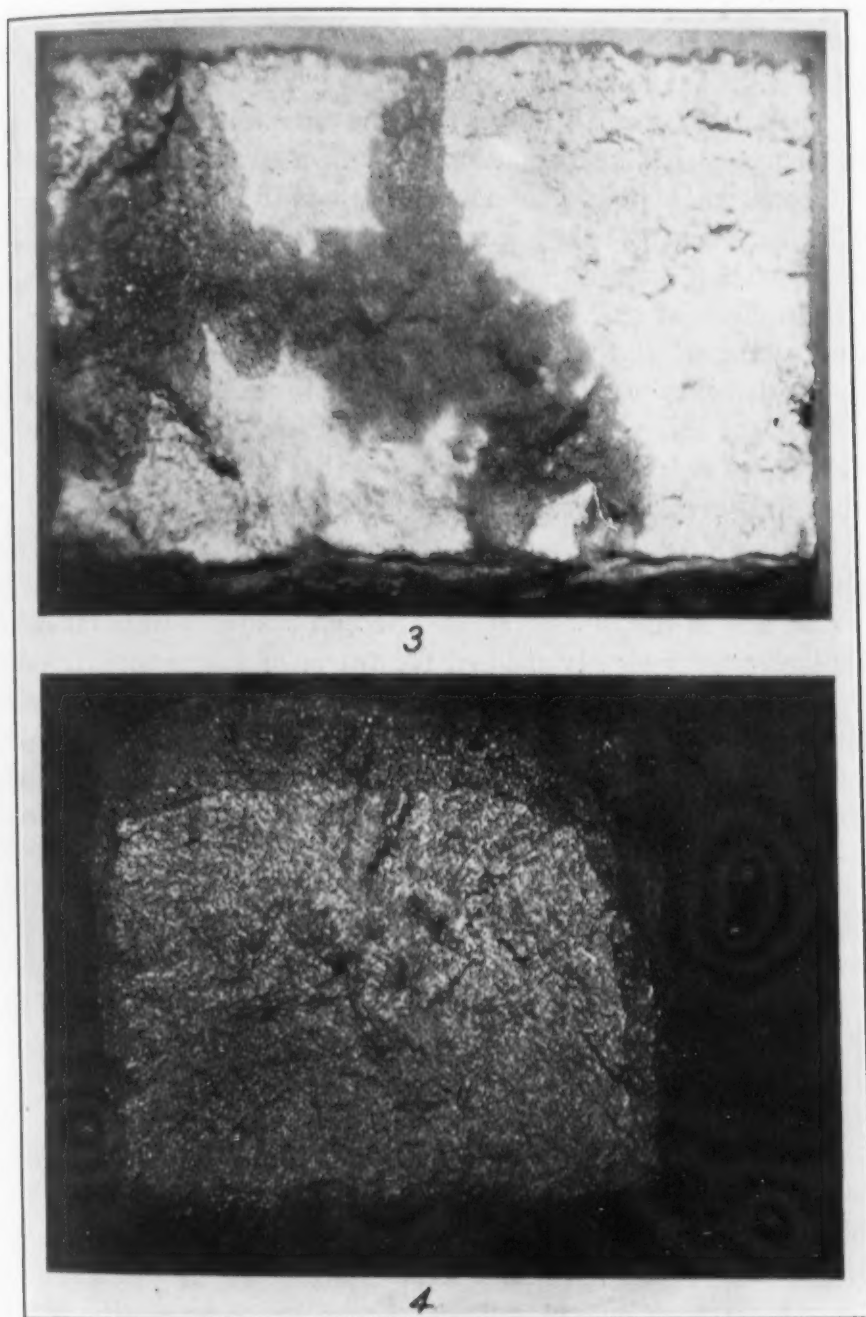
Fig. 3—Photograph at 4 Diameters Showing the Manner in Which Inclusions Occur in the Pots. Fig. 4—Photograph at 5 Diameters Showing the Scaling Effects in Box No. V.

cause so much of the trouble in the boxes. Manganese has no apparent effect on the quality of the alloy and can be disregarded,

while silicon appears to affect the scale-forming properties to some extent as No. II, the most free from scale, has a high silicon content, while No. V has much less.

The theory was advanced that the furnace conditions of three years ago caused the formation of a thin protective scale on the good boxes then in use, and that the conditions of today caused the formation of the abscesses. In order to ascertain the value of this suggestion, both a good and a poor pot was selected and some of the surface of each ground off. The abscesses on the poor box were ground off and the boxes put back in use. After a period of time these boxes were re-examined and it was found that in the good pot the same protective scale re-formed and in the poor one the abscesses reappeared. This showed that either the furnace conditions are unchanged or that they have no noticeable effect.

The accidental noting that the good box was practically non-magnetic and that the others were magnetic to a marked degree led to a side line in the investigation. Brinell readings were taken and the microsections closely studied for traces of martensite, troostite, etc. This led to the discovery that the good pot was softer than the others, was less magnetic, and as would be expected, contained mainly austenite; while the others contained varying amounts of the other structural forms of ferrous alloys. The Brinell readings were:

Box No.	Brinell Number
I	187
II	241
III	217
IV	163
V	192

MICROSTRUCTURE

It was thought advisable, before going further, to make a microscopic examination of the various parts of each box, so a number of samples were cut, polished, and etched, showing each of the following salient points:

1. A good section of pot No. I.
2. A good section of pot No. II.
3. Section cut from central point of fracture, pot II (burned through).
4. Section cut from another corner of same central point.
5. Section parallel to closed crack, pot II.

6. Section parallel to open crack, pot II.
7. A good section of pot No. III.
8. Section taken to show inclusions running to surface, pot III.
9. Section taken to show interior inclusions, pot III.
10. A good section of pot No. IV.
11. A corner of two cracks, also showing line of demarcation through pot IV.
12. A section showing a fold in pot IV.
13. A section of pot No. V showing probable effect of no aluminum.

PHOTOMICROGRAPHS

These sections, under the microscope, resolved themselves into a few main groups of which samples are shown in the accompanying photomicrographs.   (Figs. 5 to 9)

Analysis of Photomicrographs

Fig. 5 shows a typical section of the good box and about the structure desired. It is free from slag and inclusions of any kind and shows a uniform distribution of austenite and cementite. It should also be noted that the cementite is in a fairly globular condition, probably denoting a low pouring temperature, thus causing a slower rate of cooling.

Fig. 6 is almost the direct opposite of Fig. 5. It is not as clean as the first, nor are the austenite and cementite areas evenly distributed. Moreover, the cementite, while partially globular, is generally more needle-like in character. It also has a tendency to "fan" out from some common point. This condition would lead one to believe that the casting had been chilled rapidly and that no particular care was taken to keep the melt clean during pouring.

Fig. 7 shows a "dirty" section of pot No. III. Two large inclusions are shown and the structure around them portrayed. These inclusions appear to be parts of the casting which were not completely deoxidized.

Fig. 8 shows a small interior inclusion with the evenly distributed austenite and globular cementite on one side, while on the other the distribution is less even and the cementite grains approach the needle-like structure of No. 2. This would occur if one side of the box was chilled and the other cooled slowly although such an
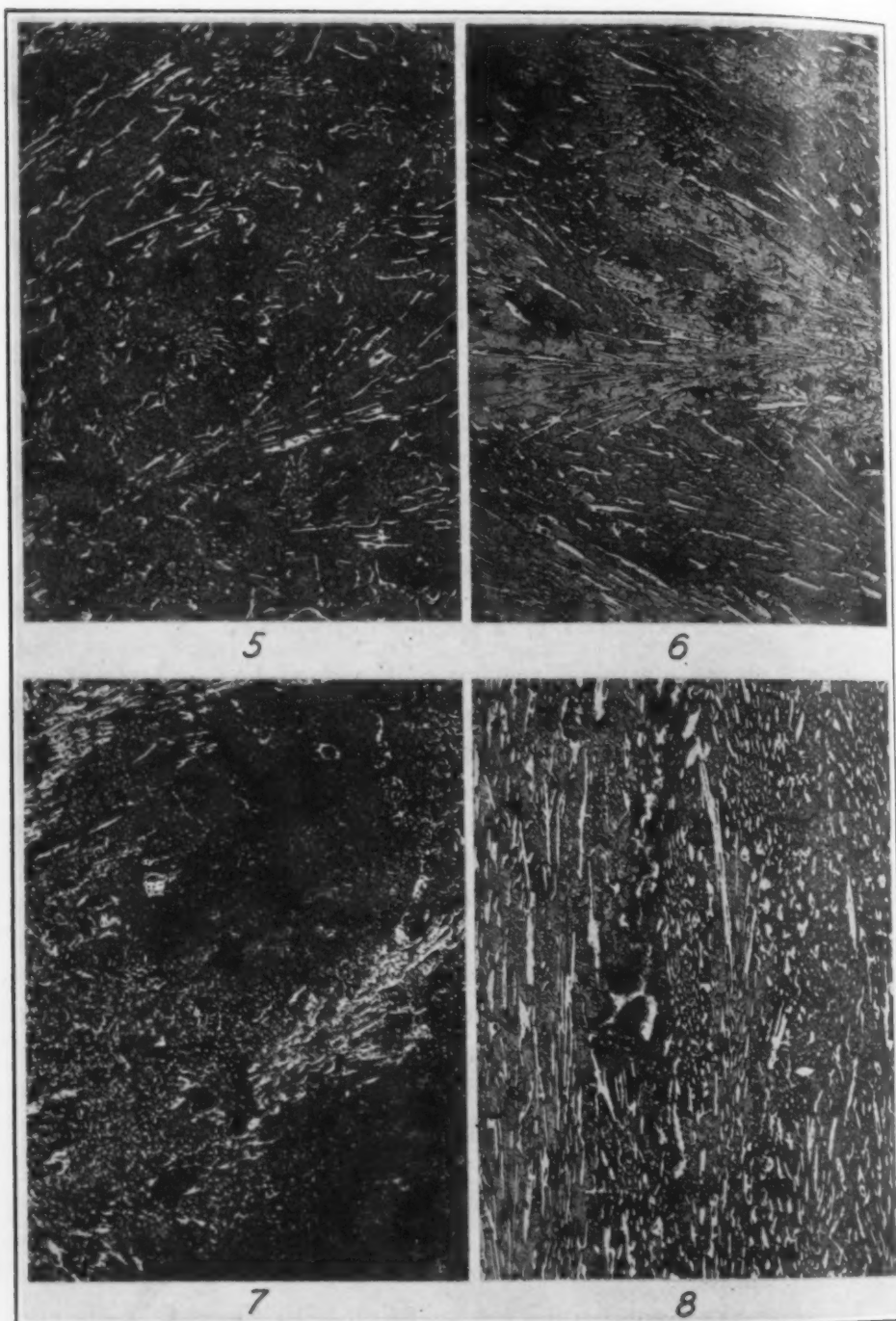
Fig. 5—Photomicrograph Showing a Typical Section of a Good Box. Fig. 6—Photomicrograph of a Section of an Unsatisfactory Box. Fig. 7—Photomicrograph of a Dirty Section of Pot No. III. Fig. 8—Photomicrograph of a Section Showing a Small Interior Inclusion. All Sections were Etched with FeCl$_3$—HCl Solution. Magnification 100 x.
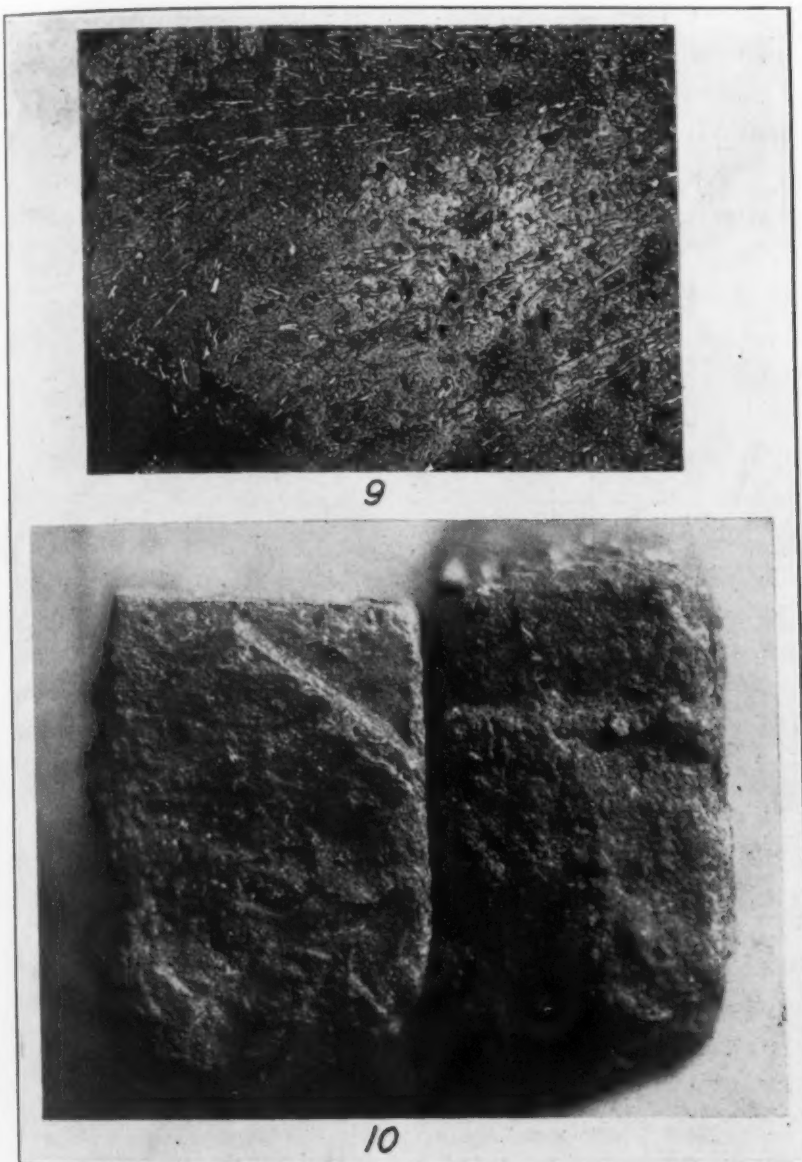
Fig. 9—Photomicrograph of a Section of Box No. V Which Failed in a Few Hours, Due to Excessive Oxidation. Fig. 10—Photographs of Samples from Test A. Both Pieces Badly Scaled.

occurrence seems unreasonable. The inclusion shown is evidently the starting point of an abscess. It has most of the characteristics shown in photomicrograph Fig. 7, including the same apparent incomplete deoxidization.

Fig. 9 shows a section of box No. V which failed in a few hours due to excessive oxidation. The analysis shows it to be normal

Fig. 6—Photograph of a Dirty a Small Interior on 100 x.

in all respects except for an absence of aluminum. The micro-structure indicates a difference in the condition of this casting as compared with box No. I. Whether this difference is due to analysis or foundry practice is difficult to determine.

Experimental Data

As was stated in the introduction, certain gases were to be contended with. In view of this fact, sections of both the good pot (No. I) and a poor one (No. III) were packed in various mixtures of compounds which were selected primarily to greatly exaggerate each of the above furnace conditions. The sections were cut approximately one inch cube and were so handled as to give at least one each of the following surfaces: a polished surface, an outside surface, and a rough fractured surface. The two sections, good and bad, were then carefully packed into 2½ x 3 inch nipples and a cap put on each end. Each test nipple was then labeled, placed in a carburizing box in a direct-fired, oil burning furnace at 1675 degrees Fahr. and left there for 240 hours. At the end of this period the nipples were withdrawn, opened, and the effect on each piece noted and compared with its companion piece. The following table shows the effects encountered.

	Contents	Effects
Test Letter A Fig. 10	Ca) Ba} Sulphide Na) Ca) Ba} Carbonate Na) Compound-Free Sulphur-Clay A predominance of sulphides, particularly barium sulphide.	Both pieces scaled badly. Uniform thin scale.
B Fig. 11	Same as A but a predominance of Carbonates, particularly Barium Carbonate.	Same as A but to a lesser extent.
C Fig. 12	Millscale-Free Sulphur-Clay-Mostly scale.	Piece from No. I no effect. Piece from No. III badly scaled and attacked.
D Fig. 13	Clay with some Sulphur	None
E Fig. 14	Carburizing Compound-Clay	None

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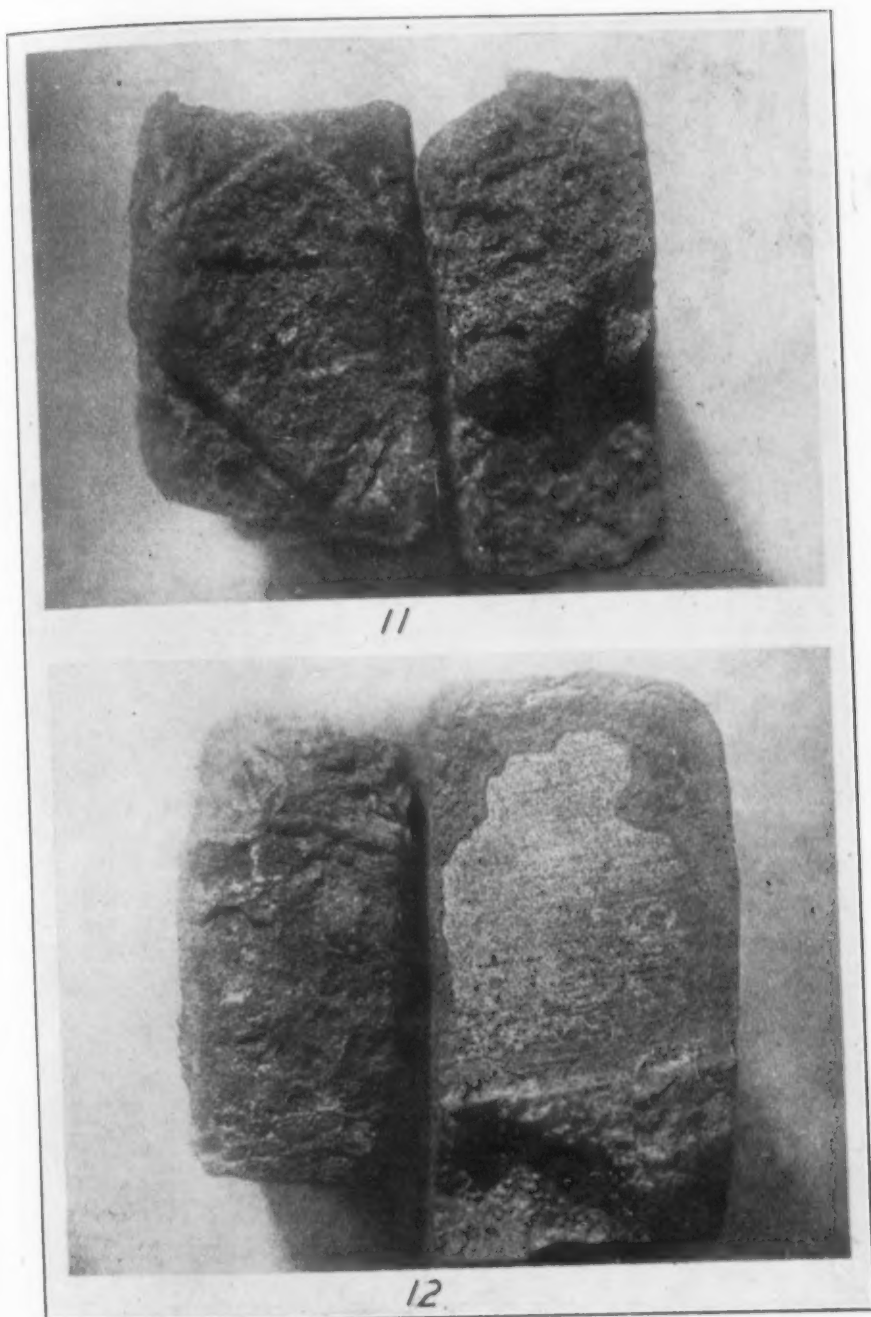
Fig. 11—Photograph of Samples from Test B. Effected Same as A in Fig. 10
But to a Lesser Extent. Fig. 12—Samples from Test C Piece No. 1 Shows Little
Effect. Piece from No. III Badly Scaled and Attacked.

As previously stated, the packing materials used were selected
to exaggerate certain furnace conditions. In A the sulphides were
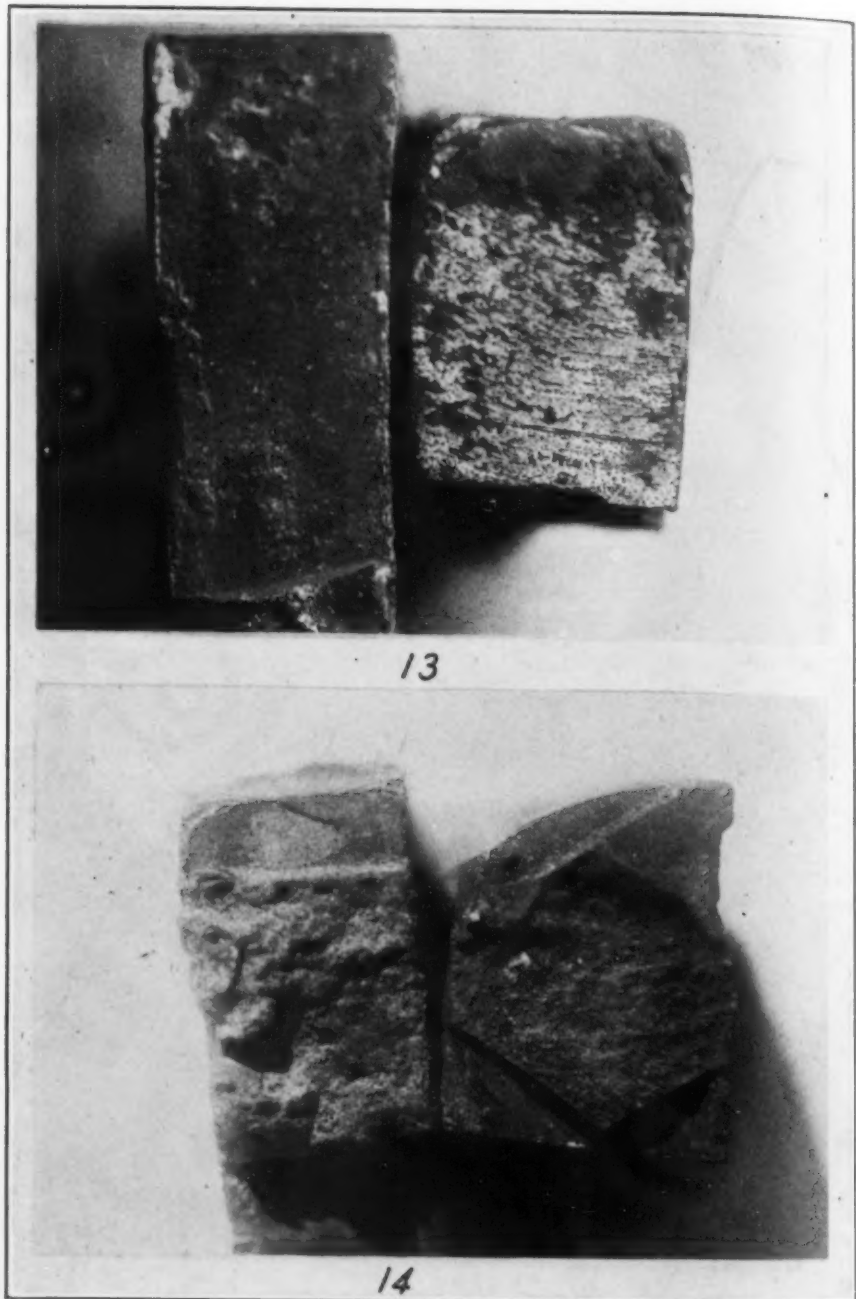
Fig. 13—Photograph of Samples from Test D. These Show No Effect. Fig. 14 —Photograph of Samples from Test E. These Show No Effect.

to show the effect of the sulphides in the compound. The carbonates were to duplicate the action of the energizer, while the mixture of

compound, free sulphur, and clay was to supply other furnace conditions.

In B the same materials were chosen but with the idea of showing the effect of the carbonates instead of the sulphides.

C was packed with millscale with the purpose of showing the effect of oxides.

D was chosen to see if the fireclay used was detrimental.

E was selected to show the effect of typical carburizing conditions over a short period of time.

From the above results it would appear that the difference in performance of the various boxes was not due to either sulphides or carbonates, since both the good and the bad samples were equally attacked. Photographs Figs. 10 and 11 show a fairly large amount of scale formation and give basis to the belief that the sulphide will, in time, attack all nickel-chromium alloy of this variety. In this statement the effect of the carbonates is purposely disregarded since test A, with a predominance of sulphides shows a greater deposit of scale than test No. B, thus giving rise to the assumption that the sulphides alone are responsible for such scale. This is further borne out by the fact that the commercial "compound" used in test E contains a large amount of carbonates which in no way affected either piece.

Oxides seem to be the cause of most of our troubles because, while not attacking a good box in any way, millscale brought about considerable corrosion on pot No. III. The effect of the materials in tests D and E was negligible, as shown in Figs. 13 and 14.

GENERAL CONCLUSIONS

From the foregoing results it seems to the author that the principal reasons for failure are:—

1. *Strains caused by un-uniform shrinkage.* This difficulty might be reduced by careful designing of the boxes, special cores, and care in the foundry. An example of failure due to this cause is illustrated in pot No. II.

2. *"Dirty" castings.* By this is meant that slag and other impurities were poured into the molds with the alloy. This was noted in most of the poorer boxes.

3. *The allotropic form of the casting.* As has been stressed above, the good box was almost pure austenite, while the others showed evidence of martensite transformation.

4. *The rate of cooling.* In the best pot the cementite was evenly distributed and in a fairly globular condition, denoting a slow cooling rate, while in some of the others an unevenly distributed, needle-like structure is predominant, showing a rapid cooling rate.

5. *Incomplete deoxidization and occluded gases.* This statement is not to be confused with a previous one made concerning the effects of oxides on the casting. The latter is probably due to a segregation of oxide-forming elements causing a subsequent deposit of oxide scale.

6. *The absence of a degasifier*, such as aluminum. This point is well illustrated in pot No. V.

It is evidently possible to make a carburizing box that will hold up for long periods of time under any ordinary conditions. If the manufacturer can determine the difference in the way in which these boxes are made, a large part of the troubles just discussed will be eliminated and most of the suspicion with which these castings are now regarded will disappear.

In conclusion, the author wishes to express his sincere gratitude for the interest and help extended him by the Timken-Detroit Axle Company.

DISCUSSION—HAIR CRACKS IN STEEL RAILS

dish in the bottom of which are two pouring holes, one toward either end. The box stands on the tops of two ingot molds on the ends of two ordinary ingot cars—the molds 3 to a car stand on steps, those farthest from the box being lowest—in this manner the box forms an apex when two cars of molds are set up. The molds connected by short iron troughs about 6 inches deep lead into the side and top of the higher molds, and provide an overflow for the molten metal from the top to the bottom mold.

Opening the ladle stopper the metal flows into the box in an ordinary sized stream, is divided into two and fills the two highest or end molds, overflowing from these into the next lowest and then into the last or lowest. There is also used a simple, cheap hot top of brick set into a recess on all four sides of the mold top—these can frequently be used 3 and even 4 times.

Ingots poured by this method have a better billet surface, decreased piping and segregation and greater uniformity. The result is obtained without radically changing the equipment used ordinarily in open-hearth plants, and without interfering with regular operations as at present carried on. No difficulty or delay has been experienced in striping the troughs or molds in two years operation.

A METALLOGRAPHIC POLISHING MACHINE

By Orlando E. Romig and J. C. Whetzel

Abstract

The available metallographic polishing machines were studied and many were tried, but there were the disadvantages of slippage of belts and friction disks, excessive noise and vibration, all of which increased the difficulty of polishing specimens. It was decided to construct a polishing machine free from these defects and one that would have sufficient power to polish large specimens such as those used for macro examination. The horizontal disk type was decided on and a machine of this type was built according to the ideas of the authors. The resulting machine was very smooth running and gave very good results.

THE microscopic study of metals has become a necessity in modern metallurgical laboratories devoted either to fundamental research or mill control. The polishing of metal specimens for microscopic examination, especially if a surface suitable for microphotography is desired, is a difficult task requiring the utmost care and skill. Long training and experience are usually essential but these are not alone sufficient to permit the preparation of a surface free from scratches under high magnifications if the proper polishing equipment is not available. Although several metallographic polishing outfits are on the market, none seem to meet the ideal qualifications for metallographic polishing. Many of the machines have too little power to polish large specimens for macrophotography. Some have the polishing disks exposed to floating dust particles. Others lack the desirable feature of variable speed which is easily controlled. A number of the outfits are equipped with belt or friction drive or a combination of the two. Slippage of belts and friction disks, together with excessive noise and vibration, eliminate some of the outfits from consideration.

After a study of the available metallographic polishing machines and the actual trial of many, it was decided to design an outfit using one of the present models as a basis. The horizontal

The authors, O. E. Romig and J. C. Whetzel, are of Vandergrift and Pittsburgh, Pennsylvania.

disk-type directly-connected to a vertically mounted motor was favored. This outfit permits the operator, while seated at a bench in a comfortable position to hold the specimen on the polishing wheel with one hand. It allows easy application of the polishing powder and makes it possible to cover the wheel when it is not in use, thus preventing contamination from dust in the air. The horizontal disk outfit designed by C. Y. Clayton[1] was taken as the basis for the improved design. Mr. Clayton's machine did not have variable speed, the size and shape of the bowl was not entirely satisfactory for our purposes, no bowl cover was supplied and it was not free from the splashing of polishing material.

A photograph of the polishing machine finally adopted is shown in Fig. 1. For direct current, a one-half horsepower electric motor having a range of speed between 600 and 3000 revolutions per minute was used. The speed is controlled by a rheostat connected in series with the field and may be further lowered if desired by inserting a resistance in the armature circuit. A one-half horsepower electric motor of the brush-shifting type was substituted for use with single phase alternating current. This motor was tested under actual service conditions and found to give nearly any speed desired between 200 and 3000 revolutions per minute although the motor is not rated for quite so wide a range of speed. Full power is not developed at the very low speeds but this is not absolutely necessary since these low speeds are used only for finishing the specimen when light pressure only should be exerted on the polishing disk. A lever is attached to the brushes of the motor, enabling the speed to be varied readily.

A high polishing speed and considerable power are desirable when polishing large specimens for macroscopic or visual examination. Such conditions are also convenient for quickly wearing down the scratches on a specimen of any size. However, a high speed gives considerable surface flow and distortion especially with the softer metals, so that a slow speed for the final polishing is essential. In fact our experience shows that with each polishing powder it is desirable to finish with the disk revolving rather slowly. When investigating the nature of non-metallic inclusions, the slow speeds are also desirable so that slag particles will not be torn out.

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[1]Chemical and Metallurgical Engineering, Vol. 24, 1921, p. 346.

The bowl and disk, together with other small parts, are made of cast bronze. This is desirable from the standpoint of corrosion resistance, since rust particles are liable to interfere with the polishing. The diameter and depth of the bronze bowl
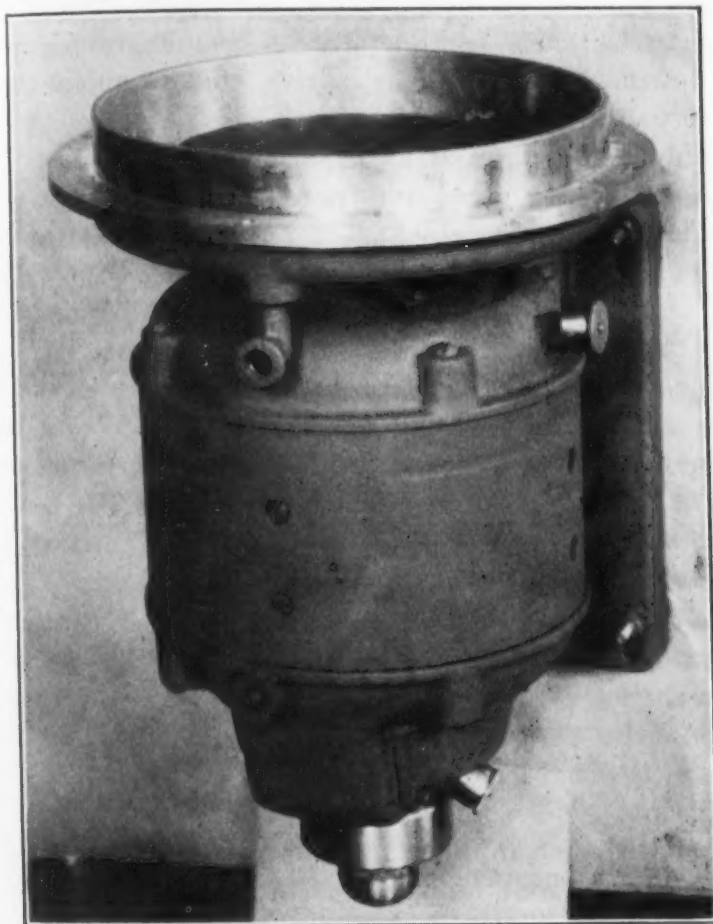
Fig. 1—Photograph of the Metallographic Polishing
Machine Described in this Paper.

prevent splashing of the polishing materials, and permit it to be cleaned with facility. It is still sufficiently large to allow easy removal and insertion of the bronze disks. A hole was drilled and tapped in the bowl for the connection of a $\frac{3}{8}$-inch iron pipe drain. An opening of at least the size indicated is essential since stoppage is liable to occur. A spun copper top with handle fits snugly over the bowl. An outside projecting rim is provided so that the outfit may be fitted permanently into a bench. An economical and serviceable bench may be constructed of steel bench legs and

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oak or birch planks. The dimensions may be changed to suit the individual needs of each laboratory. A glass of water was placed on such a table, supported by two bench legs, with three motors running at 2700 to 3000 revolutions per minute and not even a ripple could be noted on the surface of the water. This smoothness of operation, which is not common to metallographic polishing machines having a friction or belt drive, enables an inexperienced operator to polish metal specimens with ease. If the disk does not run smoothly and true even an experienced operator will find it difficult to prepare a surface free from scratches.

It is very convenient to have three motors, each a separate unit. One may be used for emery powder, another for 600 alundum or tripoli powder and a third for rouge, alumina or magnesia. By this method three men can work at the same bench. If economy in the cost of equipment is more desirable than economy of time one motor alone may be used, utilizing separate disks for each polishing powder. A tapered fit with clutch arrangement was used and has proved very satisfactory in service. It enables the operator to change polishing disks easily by simply lifting the disk off the motor shaft and substituting another disk.

A shelf built above the bench to hold aspirator bottles of distilled water from which a tube drops over each bowl is a convenient arrangement to keep the disks moist. Plunger or heavy push-button type switches with fuses may be mounted conveniently on a switchboard along the front of the bench. A starting resistance is not required for a motor of the rating used.

It is believed that an outfit for polishing metallographic specimens should be as well built as machinery used in production and an outfit built as described gives constant service with little or no attention except for bearing lubrication. Roller and ball bearings are used throughout. Although the initial cost of such machines is greater than the ordinary type yet the saving in time and the convenience in operation quickly repay the higher first cost.

Our appreciation is due the engineers of The Cincinnati Electrical Tool Company for their helpful co-operation in the design of these metallographic polishing outfits, and also to M. E. Hazlett for valuable suggestions and criticisms, and to A. G. Young for assistance in preparing drawings.

ALUMINUM BRONZE — PART II*

By Jerome Strauss

Abstract

The aluminum bronzes or aluminum-copper alloys rich in copper have been known for a number of years and have been the subject of frequent researches since the early part of the 19th century. Extensive commercial application has been of more recent origin and at present is growing at an extremely high rate.

The present paper is a review of the constitution, mechanical properties and resistance to corrosion of these aluminum-copper alloys with and without the addition of other elements. It is intended to provide those who up to the present time have been largely interested in steel and its heat treatment, with a survey of a portion of the nonferrous field in which mechanical properties, heat treatment practice and other features are closely allied to those of some common ferrous products.

(b) Effect of Added Elements—Manganese

THE influence of manganese upon the tensile properties of binary alloys of different aluminum proportions has been carefully determined by Rosenhain and Lantsberry (71) and their data upon the cast, hot-rolled and cold-drawn forms are reproduced in Figs. 19, 20 and 21. Little comment need be made concerning this data for, as the unit coordinates are the same for all graphs, recognition of the effect of the added elements is rendered easy. The data on alloys of zero manganese content are taken from Carpenter and Edwards (58). Reference to Fig. 15 and Table VI will show that except for the binary alloys containing less than 10 per cent of aluminum the ratio of maximum stress in torsion to tensile strength is greater than unity; only for the alloys of highest aluminum content is it below unity. With hot-

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*Part I of this paper appeared in the July, 1927, issue of Transactions, page 69.

Table VII

Endurance Data on Aluminum Bronze

Aluminum Per Cent	CONDITION (Temp. in Deg. F.)	Elast. Lim. lbs./sq. in.	Prop. Lim. lbs./sq. in.	Tens. Str. lbs./sq. in.	Elong % in 2"	Reduc. Area %	Endur. Lim. lbs./sq. in.	Prop. Lt. Compress. lbs./sq. in.	Com. Str. lbs./sq. in.	Shear. Str. lbs./sq. in.
5.5	Rolled, 1200 (60m.) fce cool	3,800	(a)14,500	57,800	76.5	72.0	15,200	.....	.....	.....
8.5	Rolled, 1300 (60m.) fce cool	15,000	(a)20,000	65,500	74.5	66.5	18,400	.....	.....	.....
10.0	Rolled (No treatment)	.....	.....	83,400	...	...	29,500	.....	.....	.....
10.0	1200 (60m.) air cool	5,000	(a)21,800	62,300	24.3	23.0	20,000	.....	.....	.....
	1200 (60m.) fce cool	3,800	(a)39,800	89,000	37.3	42.6	31,500	.....	.....	.....
10.05	Extruded	....	16,900	77,500	35.5	34.0	34,000	31,600	83,300	51,500
9.78	As Cast	....	5,100	59,300	20.0	28.1	22,000	6,600	82,100	40,800
...	1650 Water, 1200 (30m.) fce cool	....	24,900	77,800	14.0	19.0	26,000	28,500	94,300	43,600

(a) Proof stress or stress for permanent set of 0.0002" in 2".

Table VIII
Specific Gravity of Binary Alloys

Aluminum Per Cent	SPECIFIC GRAVITY	
	Sand Cast	Chill Cast
0.75	8.832	....
1.32	....	8.740
2.28	8.570	8.569
4.36	8.220	8.273
4.88	8.163	8.163
6.30	8.011	8.007
6.98	7.937	7.948
7.20	7.879	7.881
8.38	7.767	7.770
9.20	7.699	7.683
9.80	7.592	7.586
10.40	7.527	7.570
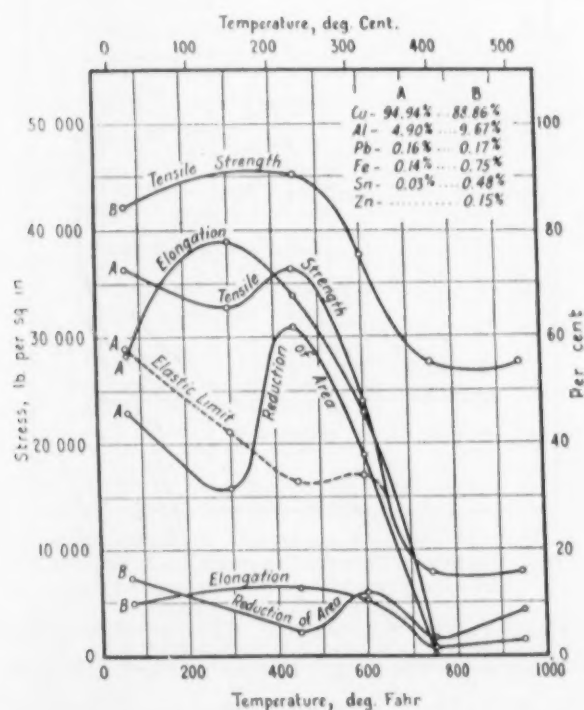
Fig. 18—Tensile Properties of Aluminum Bronzes at Elevated Temperatures (Bregowsky & Spring.)

rolled bars of aluminum manganese bronze containing 8 to 10 per cent of aluminum and with the total aluminum plus manganese not less than 10 per cent nor more than 13 per cent this ratio varied from 0.75 to 0.90 the value decreasing from the maximum as the aluminum content increased. The angle of twist per inch of length at rupture was in these alloys not greatly different from

that of the binary alloys of equal strength—67 to 184 degrees.
Typical results were:

Composition		Maximum Stress		Angle of Twist
Al.	Mn.	Torsion	Tension	Per in. of Length
10.03	0.92	65,600	85,400	70
8.91	2.98	71,300	86,500	111
7.92	4.92	72,200	81,200	184
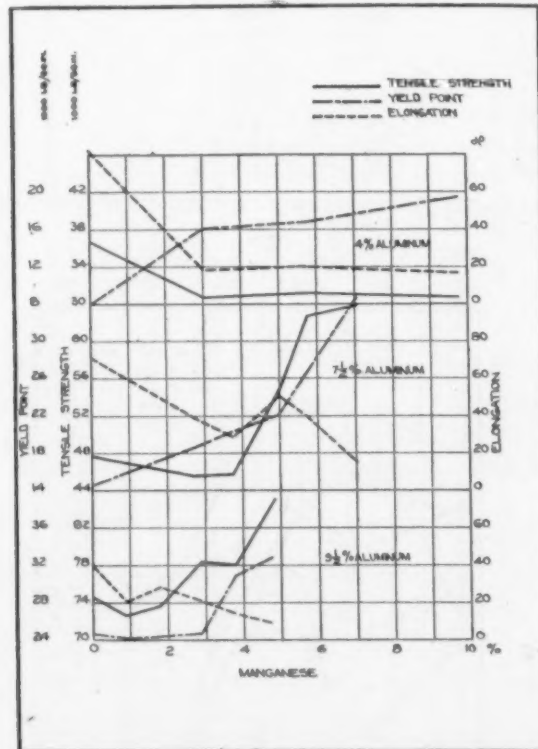
Fig. 19—Tensile Properties of Sand Cast Alumi-
num Manganese Bronzes (Rosenhain & Lantsberry.)

The relation of the properties of quenched aluminum-man-
ganese-copper alloys to those of the quenched 10 per cent binary
alloy are shown in Table IX; some very excellent combinations of
strength and elongation are available. In his studies of an alloy
containing 10 per cent of aluminum and 1 per cent of manganese
Grard (226) observed that it was generally softer than the 90-10
copper-aluminum and responded less to heat treatment; upon
tempering a slight increase in strength occurred at 752 degrees
Fahr. (400 degrees Cent.) and a slight decrease in elongation at
the same temperature. Variation in the annealing temperature
effected no substantial change in strength but a decrease in elonga-

Table IX
Effect of Quenching upon Aluminum-Copper Alloys

Al	Mn	Fe	Ni	State and Quenching Treatment	Yield Point lbs./sq. in.	Tensile Str. lbs./sq. in.	Elongation % in 2"	Reduction Area %	Izod ft. lbs. (a)
9.90	...	...	...	Sand cast	25,300	71,000	21.7	...	...
9.90	...	...	...	Sand cast 800° C. water	50,200	112,100	3.0	...	...
9.90	...	...	...	Chill cast	27,800	82,700	30.5	...	...
9.90	...	...	...	Chill cast 800° C. water	39,600	86,300	22.0	...	...
9.90	...	...	...	13/16" Hot rolled	33,100	85,300	28.8	30.8	...
9.90	...	...	...	13/16" Hot rolled 800° C. water	58,600	101,800	11.0	16.8	...
10.06	...	...	...	1" Hot rolled 900° C. fce cooled	32,200	57,500	9.0	10.4	...
10.06	...	...	...	1" Hot rolled 900° C. water	78,300	120,000	2.3	3.9	...
10.02	0.92	...	...	Sand cast	31,400	80,100	22.5	...	...
10.02	0.92	...	...	Sand cast 800° C. water	29,200	92,500	6.0	...	...
10.02	0.92	...	...	13/16" Hot rolled	51,600	96,000	22.5	33.6	...
10.02	0.92	...	...	13/16" Hot rolled 800° C. water	54,200	101,900	11.5	...	...
8.91	2.98	...	...	Sand cast	24,200	70,800	24.0	...	...
8.91	2.98	...	...	Sand cast 900° C. water	38,500	88,200	9.0	...	...
8.91	2.98	...	...	13/16" Hot rolled	44,800	89,600	39.0	43.6	...
8.91	2.98	...	...	13/16" Hot rolled 900° C. water	44,600	97,900	23.0	...	...
10.97	...	3.29	...	1" Rd. forged 900° C. water	(b)15,300	85,100	1.0	2.7	6.4
10.97	...	3.29	...	1" Rd. forged 900° C. water 400° C. air	(b)46,000	118,000	1.3	4.3	3.3
10.97	...	3.29	...	1" Rd. forged 900° C. water 538° C. air	(b)40,800	95,600	2.5	6.2	3.8
10.32	...	3.19	...	1" Rd. forged 900° C. water	(b)25,600	104,300	1.8	1.2	15.2
10.32	...	3.19	...	1" Rd. forged 900° C. water 400° C. air	(b)42,100	112,700	9.3	13.2	7.9
10.32	...	3.19	...	1" Rd. forged 900° C. water 538° C. air	(b)49,700	102,900	12.7	17.2	13.1
9.78	...	3.51	...	1" Rd. forged 900° C. water	(b)22,000	95,500	3.3	6.0	11.3
9.78	...	3.51	...	1" Rd. forged 900° C. water 315° C. air	(b)44,700	107,000	3.5	4.4	8.3
9.78	...	3.51	...	1" Rd. forged 900° C. water 538° C. air	(b)44,900	98,700	8.5	9.6	15.2
8.79	...	3.69	...	Chill cast (c) 928° C. water	(b)19,000	98,600	18.8	21.2	...
8.79	...	3.69	...	Chill cast (c) 928° C. water 370° C. air	(b)23,900	95,700	28.8	28.8	...
8.79	...	3.69	...	Chill cast (c) 928° C. water 593° C. air	(b)24,000	92,100	23.5	24.7	...
9.88	...	...	2.46	1" Hot rolled 900° C. fce cooled	40,500	71,400	12.3	13.0	...
9.88	...	...	2.46	1" Hot rolled 900° C. water	.....	101,500	5.4	5.4	...
9.44	...	...	4.95	1" Hot rolled 900° C. fce cooled	40,300	77,400	16.2	17.4	...
9.44	...	...	4.95	1" Hot rolled 900° C. water	40,300	104,300	4.2	5.5	...
9.70	...	...	7.48	1" Hot rolled 900° C. fce cooled	42,000	89,300	13.1	15.1	...
9.70	...	...	7.48	1" Hot rolled 900° C. water	44,800	111,000	6.3	5.5	...

(a) Mesnager notch, 2 mm. dia., 2 mm. deep.
(b) Proportional limit.
(c) 1¼" and 2" dia. chill bars machined to ¾" dia. before treatment.

tion occurred at 932 degrees Fahr. (500 degrees Cent.). The loss of elongation upon annealing the higher-aluminum binary alloys, particularly in the vicinity of the eutectoid transformation has already been noted; the binary alloys however lose considerable ductility by high temperature annealing (1472 degrees

Fahr. or 800 degrees Cent.) as well. Rosenhain and Lantsberry (71) observed a similar loss in elongation with 10 per cent aluminum alloys containing up to 2 per cent manganese for annealing temperatures in the vicinity of the transformation and for cast but not rolled bars at about 1472 degrees Fahr. (800 degrees Cent.) but it was much less than in the binary alloys. In con-
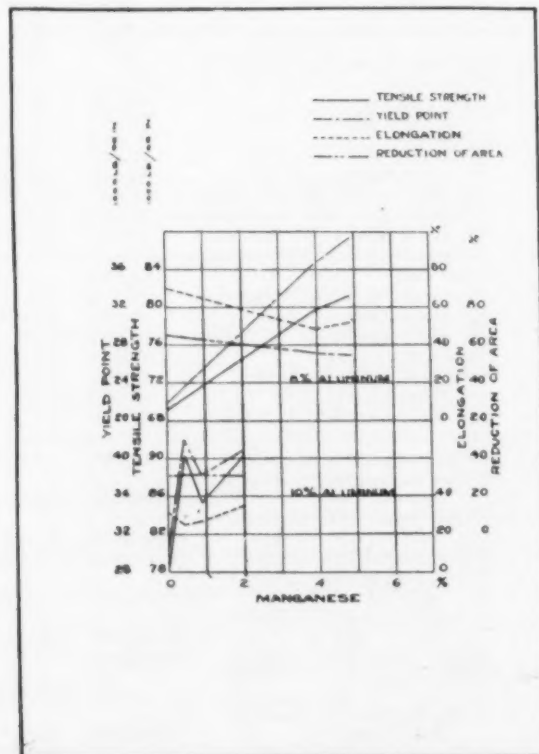
Fig. 20—Tensile Properties of 1-¼-inch Hot-Rolled Bars of Aluminum Manganese Bronzes (Rosenhain & Lantsberry.)

tradistinction to this alloys of 9 per cent aluminum and 2 to 3 per cent of manganese show an improvement in ductility upon slowless cooling from both low and high temperatures.

At elevated temperatures there is no appreciable improvement resulting from the addition of manganese to aluminum bronze; a similar maintenance of the room-temperature tensile strength is observed, in these alloys up to about 482 degrees Fahr. (250 degrees Cent.). Rolled bars of 9 to 10 per cent of aluminum and 1 to 3 per cent of manganese showed a uniform endurance limit of 27,800 pounds per square inch which is quite comparable with the values shown in Table VII.

Iron

The alteration in tensile properties resulting from the addition of iron (124) is shown in Fig. 22; the results for zero iron content are taken from Carpenter and Edwards (58). This data is for test bars cast in sand; no results of systematic investigation of rolled or drawn alloys have been found in the literature. A few
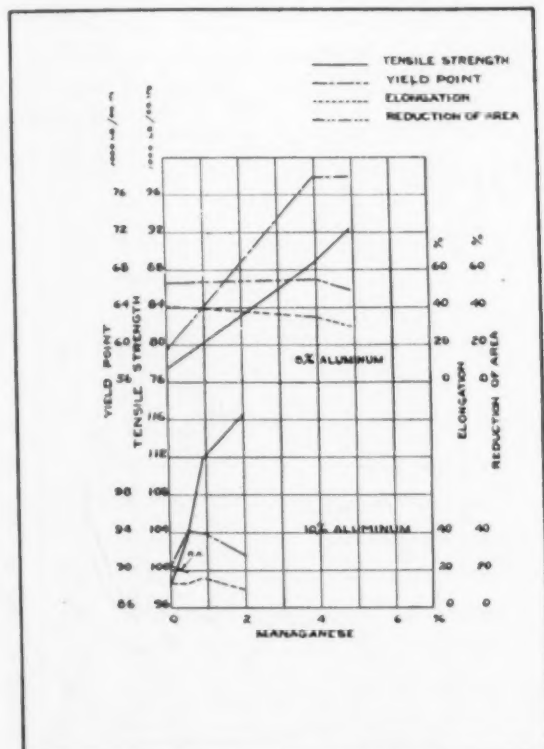
Fig. 21—Tensile Properties of 1⅜-inch Cold Drawn Bars (7/16-inch Final Reduction after Annealing) of Aluminum Manganese Bronzes (Rosenhain & Lantsberry.)

tests of quenched and tempered bars containing 8.75 to 11 per cent aluminum and slightly over 3 per cent of iron are given in Table IX. Grard (226) studied the influence of heat treatment upon an alloy containing 11 per cent aluminum, 4 per cent iron and 4 per cent nickel; with increase in annealing temperature there was no change in tensile strength but at 1382 degrees Fahr. (750 degrees Cent.) there was a small drop in the elastic limit with a simultaneous increase in elongation and impact resistance. The alloy responded to quenching and tempering to a very moderate degree but showed a slight rise in the tensile strength curve when

tempering at 752 degrees Fahr. (400 degrees Cent.) subsequent
to quenching from 1652 degrees Fahr. (900 degrees Cent.). Typ-
ical tensile properties were:

Heat Treatment	Elastic Limit lbs./sq. in.	Tens. Strength lbs./sq. in.	Elong. % in 2"
Annealed 900°C.	15,100	104,100	16
Quenched 900°C., Tempered 400°C...	80,600	117,600	4
Quenched 900°C., Tempered 600°C...	62,700	106,300	13
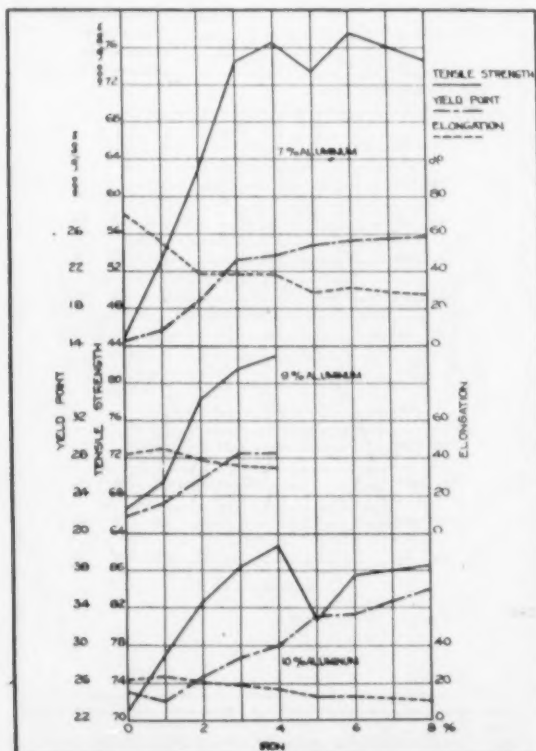
Fig. 22—Tensile Properties of Sand Cast Alumi-
num Iron Bronzes (Corse & Comstock.)

Table X contains the results of tests on bars of cold-rolled low-
aluminum bronze with and without small amounts of third elements,
after heating to various temperatures for 30 minutes and air cool-
ing. The iron is most effective in increasing the strength due to
cold working and also in retaining the high strength values upon
subsequent reheating.

Nickel

Studies of the influence of nickel upon the properties of the
aluminum bronzes have been highly productive. In Figs. 23, 24

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Table X

Tensile Tests of Cold Rolled Aluminum Bronze

Annealed 0.4" Sheet Rolled to 0.2" Sheet and Annealed as Noted

Annealing Temperature Degrees Fahr.	Al—7%				Al—7% Ni—1%				Al—7% Mn—1%				Al—7% Fe—1%			
	Prop. Lim. lbs./sq. in.	Tens. Str. lbs./sq. in.	Elongation % in 2"	Reduc. Area %	Prop. Lim. lbs./sq. in.	Tens. Str. lbs./sq. in.	Elongation % in 2"	Reduc. Area %	Prop. Lim. lbs./sq. in.	Tens. Str. lbs./sq. in.	Elongation % in 2"	Reduc. Area %	Prop. Lim. lbs./sq. in.	Tens. Str. lbs./sq. in.	Elongation % in 2"	Reduc. Area %
None	78,400	106,500	10.5	50.0	86,000	112,600	6.0	33.0	76,900	106,000	11.5	48.7	92,900	126,100	7.5	34.8
500	84,300	113,300	8.5	46.1	97,800	124,000	4.5	21.6	...	...	...	...	...	...	...	...
600	56,800	83,400	32.5	61.8	94,000	...	...	...	84,100	112,500	8.5	46.8	...	...	...	...
700	...	...	...	...	...	115,700	6.3	34.7	...	...	...	...	50,200	89,000	31.5	48.2
800	29,500	71,900	52.0	61.9	40,800	81,600	42.3	48.4	64,500	93,200	23.3	52.9	49,000	85,700	37.3	48.5
900	26,800	69,000	54.0	61.6	35,300	79,000	39.5	62.0	34,800	74,100	37.5	55.0	...	...	...	...
1000	24,100	69,100	57.0	64.0	31,900	77,600	45.8	46.8	...	...	...	...	...	...	...	...
1050	22,000	66,700	62.0	68.2	30,100	75,300	49.8	62.5	32,400	75,000	50.5	59.0	...	...	...	...
1100	16,900	64,300	65.3	65.0	20,200	68,300	55.0	53.4	17,400	66,400	60.8	57.4	...	...	...	...
1150	14,700	63,200	69.5	69.2	19,200	66,200	62.3	51.6	14,700	65,500	63.0	66.5	...	...	...	...
1200	...	...	...	...	...	...	...	...	13,700	63,500	71.5	66.8	44,200	83,900	42.0	56.0
1250	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1300	12,900	63,600	65.5	68.6	11,300	63,600	68.5	66.5	...	...	...	...	39,600	81,200	45.3	61.8
1400	...	...	...	...	...	...	...	...	...	...	...	...	20,000	73,750	54.3	53.4
1500	...	...	...	...	...	...	...	...	...	...	...	...	20,200	71,500	65.0	63.1

and 25 are given the results of the tensile tests of Read and Greaves (100) upon chill cast, hot-rolled and cold-rolled bars. From comparisons with large amounts of other data it is believed that these chill cast bars may be safely compared with other sand cast tests recorded here and the cold-rolled bars with those cold drawn in other investigations. As with other addition agents the hardening
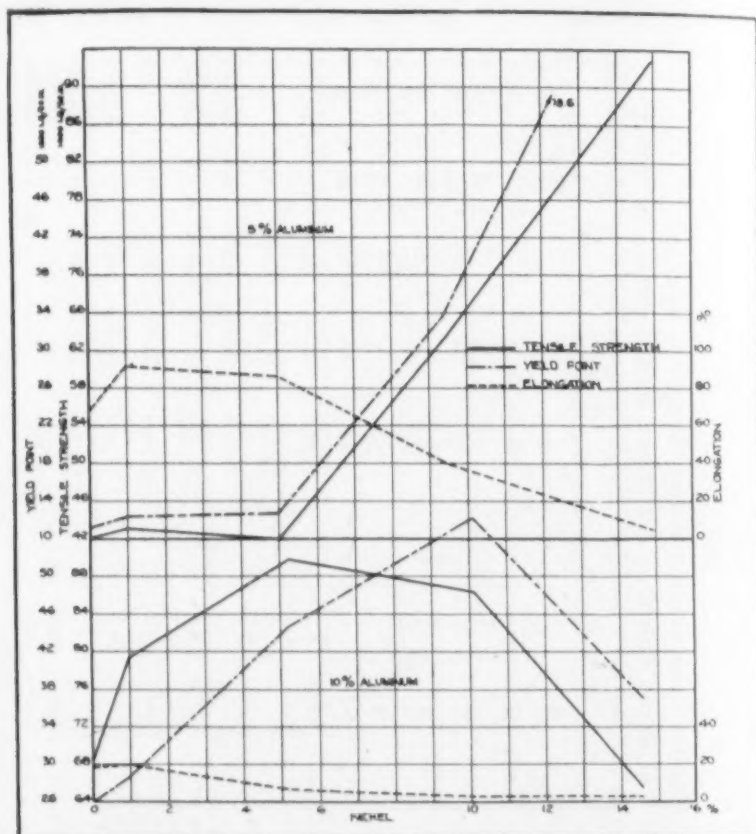
Fig. 23—Tensile Properties of Sand Cast Aluminum Nickel Bronzes (Read & Greaves.)

effects of each added per cent of nickel are less with low percentages of aluminum than with larger amounts. The tensile properties resulting from quenching 10 per cent aluminum alloys containing nickel are of about the same order as those resulting from the quenching of the other alloys studied (see Table IX). Nickel acts more like manganese and less like iron in both the low and high aluminum alloys, in that it increases ductility over that found in the binary combinations but adds less rigidity and hardness to the alloys than does iron. Differences in the behavior of iron, nickel

and manganese in these alloys are readily seen in the following figures:

Al.	Composition Fe.	Ni.	Mn.	Condition Temp. in °F			Micro. No.	Yield Point lbs./sq. in.	Tens. Str. lbs. sq. in.	Elong. % in 2"
9.26	3.07			As Chill Cast			6c	35,700	80,900	24.8
9.26	3.07			1700 Water 800	Air		6d	37,900	88,000	19.8
9.16	0.51		1.74	As Chill Cast			7a	29,300	69,100	47.5
9.16	0.51		1.74	1700 Water 850	Air		7b	30,600	75,800	23.8
8.73	0.24	4.05		As Chill Cast			7c	38,700	64,100	46.3
8.73	0.24	4.05		1700 Water 850	Air		7d	32,200	43,100	6.3–
8.31	2.44			As Sand cast			6a	28,000	75,500	48.5
8.31	2.44			1700 Water 850	Air		6b	44,300	80,400	30.8

Reference was made in an earlier section of this paper to phenomena of quenching and tempering in certain aluminum-nickel-copper alloys in which hardening resulted from precipita-
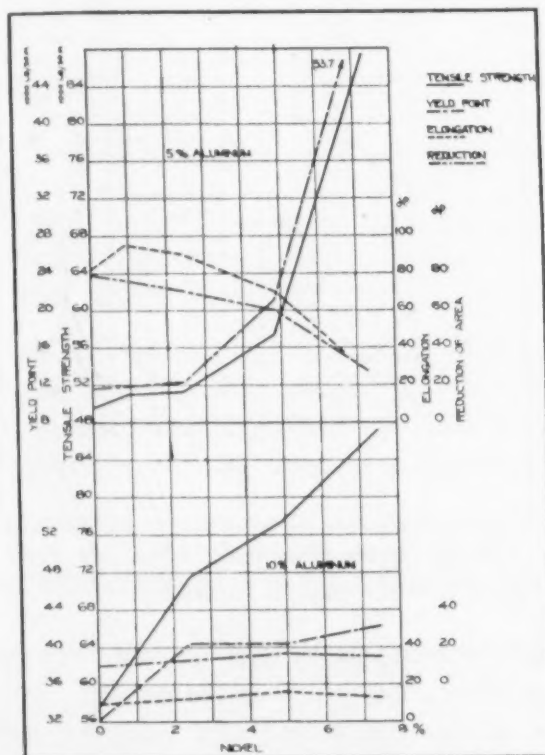
Fig. 24—Tensile Properties of 1-inch Hot Rolled and Annealed (900 degrees Cent.) Bars of Aluminum Nickel Bronzes (Read & Greaves.)

tion in a finely divided form of a structural constituent retained in solution by quenching. In Fig. 4 each pair of numbers is located at a point on the ternary diagram representing the composition of one of the alloys studied by Read and Greaves (184); the upper number is the Brinell hardness of the annealed alloy and the lower

one the hardness of the quenched alloy. To the right of AB the
alloys harden on quenching by retention at room temperature of
the beta solution; the properties of alloys of this type are given
in Table IX. In the area CDB the alloys are softer when quenched
than when annealed and with certain tempering treatments the
quenched alloys grow harder due to precipitation of the hard con-
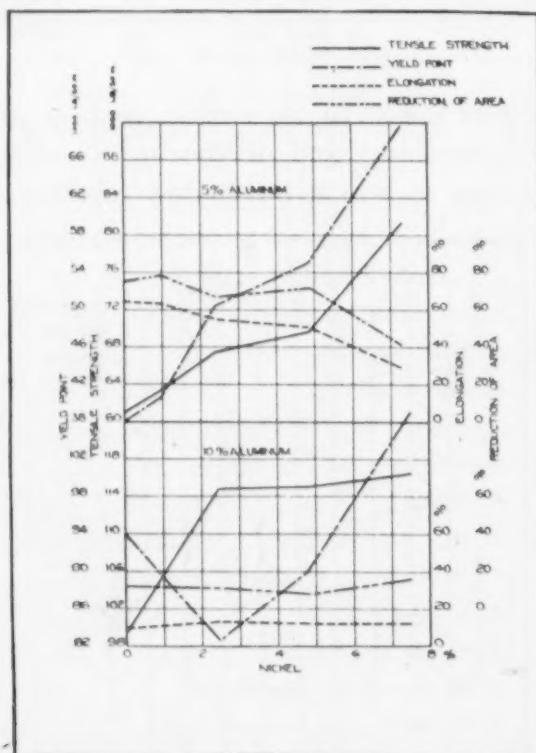
Fig. 25—Tensile Properties of 3-Pass Cold Rolled
Bars (Nickel-Free Bars Cold Drawn) of Aluminum-
Nickel Bronzes.   (Read & Greaves.)

stituent retained in solution by the quench. Typical mechanical
tests upon these alloys are given in Table XI. The exceptionally
high properties of the cold-rolled and reheated bars and the ex-
cellent combination of strength and ductility in the quenched and
tempered bars are worthy of note. Alternating stress tests of
these alloys showed an endurance limit of about 24,000 pounds per
square inch for the quenched rolled bars and about 28,500 pounds
per square inch for those annealed and slowly cooled.

Phosphorus, Manganese, Cobalt, Silicon, Tin and Zinc

Guillet's tests (251-252) of alloys containing phosphorus, mag-

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Table XI
Tests of Special Aluminum-Nickel-Copper Alloys

Composition Al	Ni	State and Heat Treatment	Elast. Limit lbs./sq. in.	Yield Pt. lbs./sq. in.	Tens. Str. lbs./sq. in.	Elongation % in 2"	Reduction of Area %	Brinell Hardness
6.22	6.62	Chill cast	.....	14,300	45,500	77.0	70.0	69
6.22	6.62	Chill cast 900° C. fce. cooled	.....	35,800	72,000	19.5	25.0	147
6.22	6.62	Chill cast 900° C. (60m) Water 700° (30m) air	.....	42,300	68,600	8.5	17.0	...
5.62	6.93	Cold rolled ⅞" diameter	29,100	72,500	85,300	27.0	47.0	176
5.62	6.93	Hot rolled ½" diameter	67,200	103,300	109,900	20.0	47.0	241
5.62	6.93	Cold rolled ½" diameter	26,900	124,000	126,500	9.0	32.0	237
5.62	6.93	½" Cold rolled, 200° C. (30m) air	44,800	118,200	119,800	9.0	38.0	...
5.62	6.93	½" Cold rolled, 300° C. (30m) air	76,200	116,800	117,600	12.0	43.0	...
5.62	6.93	½" Cold rolled, 420° C. (30m) air	69,400	112,100	115,000	14.0	47.0	...
5.62	6.93	½" Cold rolled, 500° C. (30m) air	56,000	113,100	119,000	17.0	38.0	...
5.62	6.93	½" Cold rolled, 600° C. (30m) air	35,800	81,500	100,800	28.0	40.0	...
5.62	6.93	½" Cold rolled, 700° C. (30m) air	33,600	62,700	90,600	33.0	53.0	...
5.62	6.93	900° C. Water	9,000	19,300	65,400	73.0	69.0	...
5.62	6.93	900° C. Water 600° C. (30m) air	26,800	41,300	88,900	34.0	32.0	...
5.62	6.93	900° C. Water 600° C. (120m) air	32,500	50,400	92,700	22.0	20.0	...
5.62	6.93	900° C. Water 700° C. (30m) air	29,100	50,800	96,800	26.0	25.0	...
5.62	6.93	900° C. Water 800° C. (30m) air	22,400	34,500	86,600	36.0	33.0	...

nesium, cobalt and silicon are shown in Tables XII, XIII, XIV and XV. The danger of using phosphorus or magnesium for deoxidation is apparent; small residual amounts would depreciate the mechanical properties of the bronzes so treated. The data on

Table XII
Tensile Tests—Aluminum-Phosphorus-Copper Alloys
AS CAST

Al	COMPOSITION P	Fe	Cu	Yield Pt. lbs./sq. in.	Tens. Str. lbs./sq. in.	Elongation % in 2"	Reduc. Area %	Brinell Hardness
9.71	Nil	0.39	89.73	30,200	62,100	20.5	29.3	110
9.58	0.20	1.92	88.22	28,800	43,800	6.0	14.2	178
9.45	0.36	1.60	88.89	26,900	36,700	5.0	15.5	170
9.02	0.60	1.62	88.63	18,000	23,200	4.0	...	170

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Zinc

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cobalt aluminum bronzes also furnishes another instance of dissimiliarity in the effect of this element and that of nickel on the same metallurgical product. Silicon is quite evidently not beneficial as it imparts to higher aluminum alloys brittleness without appreciable strength increase and in lower aluminum alloys the

Table XIII
Tensile Tests—Aluminum-Magnesium-Copper Alloys

| | COMPOSITION | | | AS CAST | | ANNEALED 800° C. | | |
Al	Mg	Fe	Cu	Tens. Str. lbs./sq. in.	Brinell Hardness	Tens. Str. lbs./sq. in.	Elong. % in 2"	Brinell Hardness
10.15	0.50	0.23	89.14	53,300	179	51,700	..	173
8.92	0.99	0.34	89.74	35,500	146	45,900	3.5	127
7.05	2.81	0.21	89.96	.....	107	.....	..	102

Table XIV
Tensile Tests—Aluminum-Cobalt-Copper Alloys

| | COMPOSITION | | | AS CAST | | | | | ANNEALED 800° C. | | | | |
Al	Co	Fe	Cu	Yield Pt. lbs./sq. in.	Tensile Str. lbs./sq. in.	Elongation % in 2"	Reduc. Area %	Brinell Hardness	Yield Pt. lbs./sq. in.	Tensile Str. lbs./sq. in.	Elongation % in 2"	Reduc. Area %	Brinell Hardness
9.14	0.43	0.53	89.92	28,400	47,000	12.0	15.5	116	23,500	58,400	18.0	25.8	116
8.86	0.92	0.49	89.70	22,200	47,600	16.0	28.8	102	23,500	55,400	6.5	18.1	115
6.60	2.97	0.32	90.07	31,600	54,700	4.5	15.5	157	34,400	55,700	4.5	10.1	143

Table XV
Tensile Tests—Aluminum-Silicon-Copper Alloys

| | COMPOSITION | | | AS CAST | | | | | ANNEALED 800° C. | | | | |
Al	Si	Fe	Cu	Yield Pt. lbs./sq. in.	Tensile Str. lbs./sq. in.	Elongation % in 2"	Reduc. Area %	Brinell Hardness	Yield Pt. lbs./sq. in.	Tensile Str. lbs./sq. in.	Elongation % in 2"	Reduc. Area %	Brinell Hardness
4.06	0.08	0.01	95.90	6,500	35,700	70.0	81.7	49	6,100	37,600	68.0	85.2	53
3.82	0.90	0.01	95.86	8,900	37,400	34.0	...	62	8,500	38,800	41.0	...	64
4.03	2.79	0.28	92.96	29,200	53,300	15.0	19.4	110	18,800	51,100	34.0	37.7	85
6.68	0.05	trace	93.45	8,900	42,000	58.5	...	48	7,900	43,900	71.0	73.6	48
7.00	2.78	0.05	90.27	.....	43,700	1.0	...	175	49,600	50,100	0	0	159

strength increase is not sufficient to warrant the sacrifice in ductility. A few of the author's results with the introduction of tin and of zinc into iron-bearing bronzes are included in Table XVI and Read and Greaves (119) work with tin added to the binary alloys

(partial left-margin column from preceding page)

	LED 800° C. Elong. e in 2"	Brinell Hardness
	3.5	173
	..	127
	..	102

	800° C. Elongation % in 2"	Reduc. Area %	Brinell Hardness
	18.0	25.8	116
	6.5	18.1	115
	4.5	10.1	143

	800° C. Elongation % in 2"	Reduc. Area %	Brinell Hardness
	68.0	85.2	53
	41.0	...	64
	34.0	37.7	85
	71.0	73.6	48
	0	0	159

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nary alloys

Table XVI
Effect of Tin and Zinc on Aluminum-Iron-Copper Alloy

COMPOSITION Al	Fe	Sn	Zn	Condition	Prop. Limit lbs./sq. in.	Tens. Str. lbs./sq. in.	Elongation % in 2"	Reduc. Area %	Brinell Hardness	Izod Ft. Lbs. (a)
8.71	3.05	...	...	Sand Cast	19,300	75,600	36.2	33.8	109	23.1
8.71	3.05	...	...	Chill Cast	24,000	83,200	46.9	50.5	112	50.4
8.71	3.05	...	...	Forged and Annealed	35,100	87,800	40.3	45.4	129	32.8
8.75	3.21	0.48	...	Sand Cast	20,300	79,300	45.9	41.9	102	20.1
8.75	3.21	0.48	...	Chill Cast	25,000	84,300	40.5	35.9	113	27.6
8.75	3.21	0.48	...	Forged and Annealed	31,700	88,200	41.3	42.3	130	26.5
8.67	3.21	1.98	...	Sand Cast	20,900	66,900	13.0	13.2	109	5.9
8.67	3.21	1.98	...	Chill Cast	27,600	75,300	11.2	12.4	128	5.0
8.67	3.21	1.98	...	Forged and Annealed	31,500	69,700	9.3	7.8	130	5.0
8.47	3.03	...	1.08	Sand Cast	21,400	75,600	32.8	30.7	119	24.3
8.47	3.03	...	1.08	Chill Cast	27,600	82,700	43.0	43.2	125	53.8
8.47	3.03	...	1.08	Forged and Annealed	37,200	89,000	40.3	42.0	143	43.3
8.55	2.95	...	9.53	Sand Cast	53,600	92,600	1.0	2.2	197	1.1
8.55	2.95	...	9.53	Chill Cast	59,000	95,600	0.9	1.4	207	1.3
8.55	2.95	...	9.53	Forged and Annealed	71,800	105,100	7.0	2.0	207	1.5

(a)   Mesnager notch, 2 mm. dia., 2 mm. deep.

Table XVII
Tensile Tests of Aluminum-Tin-Copper Alloys

COMPOSITION Al	Sn	AS CHILL CAST Prop. Limit lbs./sq. in.	Tensile Str. lbs./sq. in.	Elongation % in 2"	Reduction of Area %	ANNEALED Prop. Limit lbs./sq. in.	Tensile Str. lbs./sq. in.	Elongation % in 2"	Reduction of Area %
10.35	1.18	36,700	67,700	4.4	5.6	32,500	65,700	11.9	15.2
7.70	1.06	21,500	44,000	22.0	24.2	16,600	47,500	68.1	46.4
7.98	2.36	31,400	67,000	25.0	27.0	19,700	61,200	35.8	31.8
5.48	0.94	13,900	42,500	54.0	46.7	12,500	38,600	43.5	41.2
5.76	2.60	16,100	37,500	19.2	23.2	15,200	38,800	33.1	31.6
5.56	4.93	21,300	33,600	2.6	3.5	20,800	35,000	11.7	12.3
2.39	7.41	21,500	32,500	3.8	3.8	17,500	28,800	9.9	8.7

in Table XVII. Tin is not harmful at a half per cent in these bronzes but at one per cent or more it produces brittleness through a combined loss in strength and ductility. Above 2 per cent of tin hot forging cannot be successfully accomplished but by reducing

Table XVIII
Specification Values—Aluminum Bronze

COMPOSITION

Cu	Fe	Al	Sn	Impurities (Pb, Zn, etc.)
85—87	2.5—4.5	7—9	0.5 max.	0.1 max.

Material	Yield Point lbs./sq. in.	Tensile Strength lbs./sq. in.	Elongation % in 2"
Ingots	.....	75,000	30
Castings	.....	70,000	25
Rods and Bars (to ½")	40,000	80,000	20
Rods and Bars (over ½" to 1")	37,500	75,000	30
Rods and Bars (over 1")	35,000	72,000	30
Shapes	37,500	75,000	30
Sheets and Plates (to ½" and to 30" wide).....	40,000	80,000	30
Sheets and Plates (to ½" and over 30" wide)...	39,000	78,000	30
Sheets and Plates (over ½")	37,500	75,000	30

All wrought material required to bend 120 degrees around a radius equal to its diameter or thickness, without signs of fracture.

the temperature to about 1022 degrees Fahr. (550 degrees Cent.) this limit is extended to 4 per cent for aluminum percentages below 10; with up to 4 per cent of tin and 8 per cent of aluminum the alloys may with care be cold worked. Zinc is not harmful at one per cent and is not excessively damaging at 10 per cent but the added strength imparted by it may be secured along with greatly improved impact resistance by the heat treatment of some of the other three-metal bronzes just described.

Lead

As noted earlier in this report, the machining of aluminum bronze is severe upon tools and the chips are long and tough as in the machining of forged steels. To render tool wear less acute and make the metal free-cutting so as to widen its field of application, it has been proposed to introduce lead as in leaded brasses and leaded nickel silvers. But lead is not readily incorporated into molten aluminum bronze so that either tin or manganese are used to retain it in more or less uniform distribution. The physical properties are somewhat adversely affected but not to so great a degree as to make the alloy unsuitable for engineering structures. Typical test values are as follows:

Cu.	Al.	Fe.	Mn.	Pb.	Sn.	Tens. Strength lbs./sq. in.	Elong. % in 2"
87	9	3		0.5	0.5	75,700	17.0
87	10	1	1	1		71.000	16.8
89	10	1		(for comparison)		78,300	36.8
88	9	3		(for comparison)		90,100	33.5

The above were all chill castings. Considering character of finish the most satisfactory machining alloy on light turning and hand-lathe threading was the last one in the tabulation; the second alloy however was the only one that was reasonably successful on

Table XIX
Average Test Values—Aluminum Bronzes

	COMPOSITION				Physical Properties					
Cu	Al	Fe	Condition	Prop. Limit lbs./sq. in.	Yield Point lbs./sq. in.	Ult. Strength lbs./sq. in.	Elongation % in 2"	Reduction Area %	Brinell	Izod Impact (ft. lbs.)
90	10	..	Sand Cast	11,000	25,000	72,000	22	22	95	22
90	10	..	Cast and H. T.*	27,000	48,000	90,000	8	10	175	..
90	10	..	Forged and H. T.*	35,000	53,000	95,000	6	10	190	14
89	10	1	Sand Cast	12,000	27,000	74,000	24	24	95	25
89	10	1	Cast and H. T.*	31,000	54,000	90,000	10	12	175	..
86	10	4	Sand Cast	17,000	32,000	81,000	18	18	..	..
86	10	4	Cast and H. T.*	35,000	58,000	98,000	10	12	..	..
86	10	4	Forged and H. T.*	47,000	70,000	103,000	8	12	210	10
88	9	3	Sand Cast	17,000	31,000	77,000	44	36	110	25
88	9	3	Chill Cast	17,000	31,000	79,000	48	40	110	45
88	9	3	Cast and H. T.**	24,000	40,000	84,000	30	25	125	38
88	9	3	Forged	18,000	33,000	85,000	42	47	130	35
88	9	3	Forged and H. T.**	26,000	50,000	88,000	32	30	135	30

*Sections about 1½".
**Sections about ¾".
(a) Mesnager notch 2 mm. dia., 2 mm. deep.

automatic screw machines due to the ease with which chips cleared the tool.

(c) Commercial Alloys

Although many of the facts disclosed in previous sections have been available for many years and the corrosion-resistance and wear-resistance known as a result of service trials, lack of attention to established requisite foundry practice has delayed extensive manufacture and application until quite recent years. The first applications were of the binary alloys, the one containing 5 per cent aluminum in the rolled form and the 10 per cent alloy in both the rolled and cast states. More recently ternary alloys have grown in popularity; in the United States those containing iron have been

most widely used while in European countries many alloys with manganese and with nickel have found favor.

With this increased application specifications have become a necessity, those of the United States Navy Department being summarized in Table XVIII. In Table XIX will be found average production data on some binary and iron-bearing ternary alloys. It will be of use for some applications to record that the 10 per cent aluminum alloys with or without iron, as cast have an "elastic

Table XX
Average Properties—Commercial Rolled Aluminum Bronze

| COMPOSITION | | HARD | | | | SOFT | | |
Al	Fe	Tens. Strength lbs./sq. in.		Elongation %	Brinell 500 kg.	Tens. Strength lbs./sq. in.	Elongation % in 2"	Brinell 500 kg
5	..	69,000		12 (a)	130	53,000	55	60
5	..	100,000	(c)	10 (b)	...	.....	..	..
8	..	83,000		20 (a)	155	60,000	61	72
8	..	130,000	(c)	4 (b)	...	.....	..	..
10	..	96,000		5 (a)	171	80,000	33	101
10	..	125,000	(c)	5 (b)	...	.....	..	..
8	3	110,000		3 (a)	205	82,000	30	122
8	3	125,000	(c)	5 (b)	...	.....	..	..
10	3	113,000		2 (a)	183	100,000	20	120
10	3	130,000	(c)	5 (b)	...	.....	..	..

(a)   Elongation in 8".
(b)   Elongation in 2".
(c)   These values obtainable only by severely working small sections.

limit" in compression (0.001 inch permanent set on a 1.129 inch diameter, 1 inch high cylinder) of about 18,000 pounds per square inch. The 89-10-1 cast alloy when heat treated shows a compressive "elastic limit" of about 52,000 pounds per square inch and the forged and heat treated 86-10-4 alloy a value of about 60,000 pounds per square inch.

Average values for the rolled commercial alloys[3] are given in Table XX. Very high tensile strengths may be secured by cold working these metals as illustrated by some tests of the author on 0.037 inch strip of 88 copper, 9 aluminum, 3 iron, viz: a tensile

[3]H. A. Bedworth, American Brass Co., in private correspondence.

strength of 150,100 pounds per square inch with an elongation in 2 inches of 2.8 per cent.

In commercial production of heat treated articles it is often advantageous to know the effective depth of hardening of the metals being fabricated. The 88-9-3 copper-aluminum-iron alloy cannot be caused to develop increased tensile strength by quenching in cool water in the usual manner, when over 0.75 or 1 inch in thickness. Small variations in aluminum content have a great influence upon this limit of hardenability. The 90-10 alloy hardens completely in 1½ inch sections, the 86-10-4 iron-bearing alloy in about 2½ inch sections and the 85-11-4 iron bearing alloy in 3 to 3½ inch sections. As an illustration, 86-10-4 alloy 4 inches in diameter forged bars quenched from 1680 degrees Fahr. showed 32 Rockwell hardness (C scale, 150 kilogram load) at the surface and 11 at the center and quenched from 1580 degrees Fahr. 22 Rockwell at the surface and 11 at the center; similar bars of the 90-10 alloy hardened to 27 at the surface and–6 at the center from 1680 degrees Fahr. and 22 at the surface, and–8 at the center from 1580 degrees Fahr.

V. OTHER PROPERTIES

(a) Electrical, Thermal, etc.

It is not proposed to burden this paper with physical data of rather infrequent use in metallurgical work; a few of the more common constants are included here and for other data recourse must be had to the appended bibliography.

The specific gravity of the alloys taken from Reader's work (229) appear in Table VIII. Alloys containing above about 7.5 per cent of aluminum are lighter than carbon steels (mean specific gravity about 7.83).

This same investigator has found an appreciable expansion during the solidification range which reaches a maximum at 4.5 per cent of aluminum and is zero at the eutectic composition, then increasing rapidly as the aluminum content is further raised. Subsequent shrinkage is, of course, high and Endo (273) records 4.27 per cent for an alloy of 12.9 per cent aluminum. He gives the mean coefficient of thermal expansion of the same alloy over the range of 68 to 1832 degrees Fahr. (20 to 1000 degrees Cent.) as 0.0000705. The patternmaker customarily allows for a contraction of $\frac{7}{32}$ inch per foot. Important volume changes occur at the

eutectoid transformation also. The thermal conductivity has been determined by Williams and Bihlman (247); these investigators report a mean value of 0.174 over the range of 266 to 662 degrees Fahr. (130 to 350 degrees Cent.) for an alloy containing 9.09 per cent aluminum and 0.47 per cent tin.

Pecheux (64) has determined values of electrical resistance as follows:

Aluminum Content	Specific Resistance at Temp.t.
3%	$8.26\,(1 + 0.00102t + 0.000003t^2)$
5	$10.21\,(1 + 0.00070t + 0.000002t^2)$
6	$11.62\,(1 + 0.00055t + 0.000002t^2)$
7.5	$13.62\,(1 + 0.00036t + 0.000001t^2)$
10	$12.61\,(1 + 0.00032t + 0.000002t^2)$

The permeability of the alloys is extremely low, that is, they are practically non-magnetic.

(b) Corrosion

It is the resistance of the aluminum bronzes to the corrosive action of many agents that, combined with the excellent physical properties, has been responsible for their commercial development. They are not in any sense nontarnishing for under certain conditions green to brown films form rapidly on fresh surfaces; but in respect to deterioration and loss in strength they have proven in many instances to be practically immune.

Carpenter and Edwards (58) tested their alloys in sea water and in fresh water. In the former, alloys of 3 to 10 per cent aluminum showed practically no weight loss and were much superior to Muntz metal and naval brass; the one per cent aluminum alloy lost less than the copper-zinc alloys but was poorer than the other aluminum bronzes. In sea water in metallic contact with medium carbon steel, none of the copper-aluminum or copper-zinc alloys lost in weight. In contact with the steel in fresh water there was slight corrosion of all the copper alloys with the copper-zinc slightly better than the copper-aluminum. The author's own experiments with aluminum bronzes and aluminum iron bronzes in actual service and when tested by a sea water spray have proven them to be equally as resistant to deterioration as any other copper alloys not containing large amounts of nickel and greatly superior to manganese bronzes.

Alloys of 9 to 10 per cent of aluminum with 1 to 3 per cent of

manganese were found by Rosenhain and Lantsberry (71) to differ only little from the binary alloys in their behaviour in fresh and sea water. There is a tendency to lose more weight when alone and less when in contact with steel than in the case of the binary alloy, with the exception that with 3 per cent of manganese all losses were smaller than in the alloy without manganese; all of the weight losses were, however, of extremely small magnitude.

Read and Greaves (100) made extensive corrosion tests of their aluminum-nickel-copper alloys both annealed and cold-rolled, not only in sea water and fresh water but in alkaline and in acid solutions as well. Nickel was found to increase the resistance of 1.5 and 10 per cent aluminum bronzes to sea water to a marked degree but not to influence the weight loss in fresh water. All of the bronzes were superior to Muntz metal and naval brass in fresh water, and in sea water only those with 1 per cent aluminum and less than $3\frac{1}{2}$ per cent nickel were not markedly superior to the brasses. In both 5 per cent and 10 per cent aluminum bronzes nickel decreased the losses in alkaline solutions; in the former nickel did not influence the resistance to acids but in the latter weight losses increased rapidly upon the addition of an increase in nickel.

Read and Greaves (119) also found that the introduction of tin did not greatly affect the loss in weight of aluminum bronzes upon exposure to sea water and fresh water. With large amounts of tin, pitting occurred (a phenomenon not often found in aluminum bronze) particularly in fresh water; these high-tin alloys are not, however, of technical value as their mechanical properties are undesirable.

In addition to these experimental determinations it is pertinent to record that as a result of actual trials, aluminum bronzes are technically serviceable in contact with sea water, cold and hot dilute sulphuric acid, certain concentrations of cold hydrochloric acid, alkaline liquors and a great number of neutral and acid salts.

VI. APPLICATION

The three factors responsible for the varied uses of these metals are the high strength combined with either very high or moderate yet safe ductility, low coefficient of friction against steel and some other metals, and stability when in contact with many corroding media.

Because of their strength properties and resistance to sea water they have been applied as highly stressed structural members in auxiliary equipment on board ship, in submarine gun mounts, and in aircraft construction. They are employed in large quantities in pickling equipment for crates, racks, supporting rods, tank rods, etc. In pumps, fans and exhaust ducts appreciable amounts of these alloys are applied.

Their bearing qualities combined with their strength have brought the aluminum bronzes, particularly those containing iron, into the field of worm-wheel and gear construction so that parts of this character made of these alloys are now found in automotive trucks, elevator equipment, gun mounts, etc. The high resistance to compression also renders the forged and heat treated iron-bearing aluminum bronze suitable for roller and roller path construction where corrosive influences are present and loads are moderate and for large cylindrical bearings at the surface of which speeds are low but loads are extreme.

VII. Bibliography

The bibliography contained in the following pages cannot be stated to embrace all publications in which mention has been made of copper-rich aluminum-copper alloys but it is believed that all original investigations in which they have played a principal part have been included and, along with them, all other articles that are readily accessible. It will, it is believed, provide the investigator with all of importance and value that has been uncovered in the study of these alloys.

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DISCUSSION

Written Discussion: By G. F. Comstock, Niagara Falls, N. Y.

This complete and scholarly paper is a valuable contribution to the literature on aluminum bronze, as practically all the previous information on the subject as well as the fruits of the author's experience are here collected together. The writer is not able to add anything really important in this discussion; but there are a few minor points on which Mr. Strauss's opinions or results seem to differ from his, and perhaps it would be worth while to present briefly this slightly different view point.

In his discussion of melting practice the author seems to favor the idea that oxidation is the chief trouble to be avoided, and is a cause of serious dross formation in castings. Since the appearance of the paper by Woyski and Boeck on "Gas-Absorption and Oxidation of Nonferrous Metals" *Transactions*, A. I. M. E., Vol. LXVIII, P. 861), however, it is becoming more and more generally accepted that melting must be carried out in a neutral or slightly oxidizing atmosphere to avoid gas absorption from a reducing atmosphere in the furnace and porous castings. A skin of oxide is always formed on the surface of the melt, but it does not become too thick or spread into the metal below when the usual covering of charcoal is present on the pot. The dross that gives trouble in the castings is formed on the surface of the stream of metal in pouring, and the extent of this trouble is proportional to the agitation produced in filling the mold. From microscopic examination of drossy castings that have been difficult to machine, the writer is convinced that it is generally sand, and not alumina, that dulls the machining tools. The cause of the inclusion of the sand in the metal, however, is the folding-in of the alumina skin of the alloy when the mold is filled. This tough skin or dross picks up some grains of sand from the mold, and when it is mixed with the metal on account of agitation in pouring, it

carries the sand grains into the metal with it. When the machining tool hits a sand grain, the grain is shattered and a white powder is seen that may be mistaken for alumina. The microscope shows that alumina inclusions in bronze are too small and too intimately mixed with metal to be visible to the unaided eye as a separate powder. It is hard to see how they could have much effect in dulling the edge of a tool, but of course the ruinous effect of a sand grain on a cutting edge is obvious.

In the writer's opinion, the author does not have exactly the right conception of the function of an iron content as a preventive of the bad
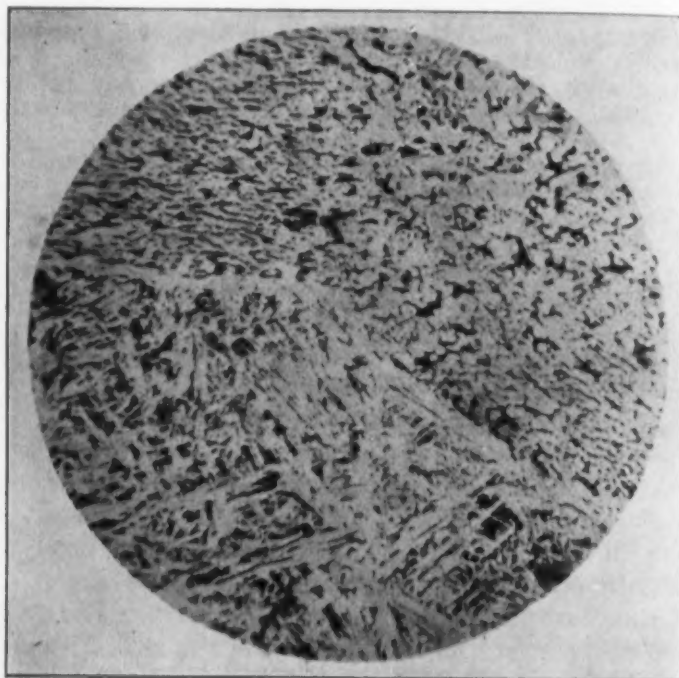
10.5 Per Cent Aluminum-Bronze (1 Per Cent Iron) Heat Treated. Quenched from 850 degrees Cent. Reheated to 650 degrees Cent. 200x.

effects of slow cooling, or the so-called ''self-annealing'' of aluminum bronze. Iron does indeed decrease the grain-size, but has practically no effect on the change of beta into the weak and brittle eutectoid. The author's Fig. 11 illustrates these facts, and does not substantiate the statement that iron ''affords the desired cure'' for the eutectoid formation. The cure is really effected by decreasing the aluminum content so that there is an unimportant amount of (beta) present to be changed into eutectoid; then the iron content may be adjusted to meet the requirements for tensile strength.

The very fine structures possible of attainment in aluminum bronzes of around 10 per cent aluminum by double heat treatment are not illustrated in this paper, yet it would seem that they are rather important as being necessary for the best mechanical properties. The alloy must first be quenched so as to give a purely martensitic (beta) structure, with all the primary

(alpha) in solution. Then upon cautious reheating, the alpha is formed in fine particles. The accompanying illustration shows such a structure in an alloy containing about 10.5 per cent aluminum, quenched from 850 degrees Cent. and reheated to 650 degrees Cent., magnified 200 diameters. Even finer structures may be obtained in small castings with a lower reheating temperature.

The elongation curve in Fig. 17 does not seem to be correct, nor to agree with the text, which states rightly that there is 90 per cent decrease in elongation on quenching 10 per cent aluminum bronze in water from 800 degrees Cent. Is there an explanation for the apparent error in Fig. 17?

In Table II there is also a figure that does not seem correct. Why should there be such a difference in the properties of water-quenched 9.9 per cent aluminum bronze, between sand-cast and chill-cast bars? The value of 22 per cent for elongation of the latter seems high, and it looks as if this specimen had not been heated enough to dissolve all the primary alpha constituent before quenching. The properties of the quenched sand-cast bar, however, indicate that it had a completely martensitic or beta structure.

A. B. KINZEL: Mr. Strauss has mentioned the use of scrap material for making melts and advises strongly against it. Undoubtedly if we have very pure materials to start with we are apt to get better properties in the resulting product. However, it is quite possible that we would get equivalent properties in specific cases when impure material is used as the source, providing proper melting and refining methods are used. It is obvious that the way to study this problem is not by means of individual cases, as these give evidence both pro and con. The problem should be studied by means of the theory of probability. If we plot probability curves of the resulting properties against initial impurities we get the probability of getting certain qualities as a function of the state of the material which is used. We may find that with some types of material the use of scrap is justified.

O. W. ELLIS: There are one or two points that are of considerable interest to me in view of the fact that for quite a time I have been directing my attention to nonferrous materials. One in particular is that of the coefficients of equivalence of the various elements that are added. I should like to ask the author a question. Is it really possible to accurately determine or to accurately estimate the coefficients of equivalence by the means that he has suggested in the paper?

Another point which comes to mind is this, that the coefficients of equivalence of various elements may be determined by examination of the structure of various complex alloys in different conditions. Of course, in these experiments one always makes the attempt to have a certain definite rate of cooling, so that one can state that the coefficients of equivalence refer to alloys that have cooled at a certain definite rate. If these rates are varied, one gets quite large variations in the coefficients of equivalence, and this fact, I think, is of considerable importance when coefficients of equivalence are being applied to practice.

Manganese, one of the elements to which the author has referred, is a particularly interesting addition agent, and I should like to ask the author

a question concerning its effect upon the structure of these alloys when added in small quantities.

Insofar as bronze is concerned (tin-bronze) the coefficient of equivalence of manganese is such that one would expect the substitution of tin by manganese to result in what would be equivalent to the addition of copper to the alloy. That is to say, the proportions of alpha and of delta constituent in the alloy would be changed so as to give one a larger proportion of alpha and a reduction in the content of delta. Now, an increase in the content of alpha normally means a reduction in the hardness of bronze. If one increases the tin content in a straight bronze, one increases the hardness; if one reduces it, one reduces the hardness. As already stated, the addition of manganese is equivalent to reducing the tin content and one would expect a reduction in hardness on that account. Actually, however, the first additions of manganese to a tin-bronze result in an appreciable increase in the hardness of the bronze. I am referring now to the Brinell hardness. If one adds 2 per cent manganese to the bronze, however, the hardness drops down considerably; 3 per cent gives a still further drop. Thus the first addition of manganese has the effect of increasing hardness, which is directly opposite to what one would expect from a knowledge of its coefficient of equivalence. This effect is entirely due to the great refining influence of manganese.

What I should like to know is whether the author has noted that grain refining influence, which appears to apply both in the case of steel and in the case of tin-bronze and appears also to apply in the case of brasses, in the case of these aluminum bronzes.

There is just one little criticism of a statement that the author makes which I view from the standpoint of a physical metallurgist. He says on page 8 of his paper: ''The fictitious composition of a two-component, three-metal brass was described as those percentages of copper and zinc that would yield a microstructure showing the same volume proportions of the two constituents as were actually present in the alloy being dealt with.'' I think what really should be said is, ''a two-phase, three-component brass,'' or ''a two-phase, three-metal brass,'' not ''a two-component, three-metal brass.''

E. M. WISE: There is one thing that I would like to point out in reference to equivalents. It was partly touched on in reference to the care necessary for securing uniform conditions for determining the coefficients of equivalence. To be of real value the coefficients of equivalence must be determined at the temperatures at which we are really interested. For instance, it is well known that the addition of nickel to a copper-nickel alloy will materially alter the solubility relations so that it is possible to heat treat the alloy and secure a considerable increase in strength and hardness.

It is obvious that where temperatures are variable, we must be sure that we are computing our equivalents under the conditions that are of interest to us:—do not compute them for 1000 degrees if you are interested in the properties of room temperature and visa versa.

SAM TOUR: Mr. Strauss is to be complimented and congratulated on this very good paper. It certainly covers aluminum bronzes and is one of the

best that I have heard. I am sorry that I have not been able to study it out beforehand as I should be able to take up several important points in it.

There is just one thing that bothers me a bit and that is, again, on this question of equivalents. I gathered from the reading of the paper Mr. Strauss's statement that manganese acted similar to aluminum on the copper-aluminum binary, but with possibly a little less degree of efficiency. In other words, the equivalance of manganese would be below one, compared to aluminum, and one would expect that adding a little manganese would give only such properties as one would gain by adding a little more aluminum.

In our practice, in making up a considerable tonnage of this alloy, we have not found this to be the case, and I would like to ask the author just wherein it is possible for his conclusions to fall short in practice.

Author's Reply to Discussion

Such an extended discussion of a paper completed too late to permit of preprinting, and especially since it is devoted to a group of nonferrous alloys, is indeed stimulating.

Mr. Comstock's discussion of inclusions of alumina (and sand) deals solely with sand castings. Mention has not been made in the paper of the influence of the furnace atmosphere; one that is not reducing in character must, of course, be used for production of the best castings since the aluminum bronzes, like other high-copper alloys, suffer from absorption of reducing gases. But it is necessary as noted in the paper, to distinguish between alumina formed in the melting and alloying, and that due to agitation, either in the melting chamber or in pouring. The state of subdivision is different and whereas the influence of finely divided alumina, which, undoubtedly, does not coalesce readily at molten bronze temperatures, may not be important in mechanical tests of castings, it may be of serious moment in transverse tests of forgings; its influence on cutting tools is no doubt inappreciable. The massive alumina due to agitation may gather hard mineral particles in refractory molds, but this explanation does not account for a skin on ingots made in uncoated metal molds, that rapidly dulls the edges of cutting tools, regardless of their heat treatment and composition, although the metal immediately below this scabby surface cuts freely, without excessive tool wear.

With regard to "self-annealing" of alpha—beta binary alloys, the influence of iron upon grain size (aluminum percentage constant) is clearly shown by Figs. 9 and 10 and Figs. 11A and 11C. It is stated that in slow cooling of the binary alloy the "individual particles" of the two phases in the eutectoid "become quite coarse;" surely Figs. 11B and 11D illustrate the refinement due to the iron. Mr. Comstock should have quoted the entire statement: "Iron in amounts over 3 per cent *with adjustment of the aluminum content to meet the required mechanical properties*, affords the desired cure." Iron added to an alpha—beta alloy of given aluminum content does decrease grain size and restrain the formation of coarse eutectoid and therefore overcomes "self-annealing;" it results in better elastic strength and ductility in heavy cast masses in spite of increased hardness. Iron added

as a substitute for part of the aluminum to secure equal tensile strength with greater ductility is another matter; other elements have similar influences; this procedure usually results in lower elastic strength.

The heat treatment of 10 per cent aluminum bronze castings described by Mr. Comstock is rather widely practiced. This heat treatment has been mentioned for forged metal but photomicrographs were not included. It should be noted that, although the alpha is very finely divided, the grain size is large (part of only four grains in Mr. Comstock's photograph); this is of frequent occurrence and under these conditions how ductility and resistance to impact may occur; this is a fruitful direction for research.

The curves of Fig. 17 shows the *changes* in properties (increase or decrease) due to quenching, expressed as the actual *number of units alteration*, these units being those used in expressing the results of the tension test. In the text, references are made to *percentage change*, computed on the basis of the values before treatment.

The data of Table II is that of Carpenter and Edwards. The particular figure referred to by Mr. Comstock is, no doubt, the result of faulty experimental procedure but was quoted in order that the series would be complete; attention should have been called to this irregular result.

Dr. Kinzel's suggested application of probability methods to the results obtained from the use of raw materials of varying composition is sound from one viewpoint. But the average manufacturer must face production costs and a supply of such unsuitable scrap as could not yield satisfactory product, in a plant not manufacturing a continuous large tonnage of aluminum bronze, might prove disastrous. Where metallurgical control is adequate cautions of this sort need not be considered, but there are many plants not so equipped and to them the safer procedure is a necessity.

The author has not had occasion to note the influence of small amounts of manganese upon either tin bronze or aluminum bronze but Prof. Ellis' explanation of its effects upon the former alloy may cover only part of the mechanism of the change in properties. Change in grain size, when produced, is no doubt a factor. But two other effects are being observed and their rate of change with increase in manganese, may be quite different—the increase in the hardness of the alpha phase due to the presence of "stranger" atoms in the lattice and the decrease in the quantity of the delta phase. With lower manganese percentages the former may exert a predominating influence. The amount of tin in the bronze experimented upon may also be of importance since a small change in the amount of eutectoid in a 9 per cent tin alloy would be proportionately much greater than an equal change in a 12 per cent tin alloy.

Prof. Ellis' terminology is, of course, correct. In regard to his comment as well as that of Mr. Wise on the subject of the coefficients of equivalence, it is well known that the degree to which a phase stable at some elevated temperature is retained at room temperature or is transformed into other phases, is a function of the rate of cooling. Hence in the use of these equivalents, deductions must be based upon observations made under like

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THE CONSTITUTION OF STEEL AND CAST IRON
PART X

By F. T. Sisco

Abstract

*The present installment, the tenth of the series, dis-
cusses the effect of the four common elements, silicon,
sulphur, phosphorus and manganese on the iron-carbon
alloys containing 2.00 per cent or more carbon—(The
cast irons). Each element is discussed under two heads;
first, the amount of the element in cast iron and how the
percentage is controlled; and second, the effect of the
element on the constitutional changes, microstructure
and properties.*

IN previous installments our discussion of the iron-carbon alloys
containing between 1.70 and 5.00 per cent carbon has consid-
ered this series to be alloys of the pure metal iron and the element
carbon. We have viewed from a theoretical standpoint the con-
stitutional changes in this series as they occur in these pure alloys.
The iron-carbon, or steel and cast iron alloys as they are produced
in our steel plants, blast furnaces and foundries are rarely pure;
they contain in addition to carbon, appreciable and sometimes large
amounts of silicon, sulphur, phosphorus and manganese. In addi-
tion to these four common elements which are always present, we
occasionally encounter copper and arsenic, and frequently we meet
with steels and cast irons that contain various alloying metals:
nickel, chromium, vanadium, titanium and others.

The effect of silicon, sulphur, phosphorus and manganese on
the constitutional changes and structure of the steel series has al-
ready been considered[95]. In the present chapter we will take up

[95]See TRANSACTIONS, Vol. XI, January, 1927, p. 115

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Corps, War Department, Wright Field, Dayton, Ohio.

the effect of these four elements on the alloys containing between 1.70 and 5.00 per cent carbon (the cast irons).

The behavior and effect of these elements in cast iron may be naturally discussed under three heads: (a) how much of the element is present in the iron and how this percentage is controlled; (b) the effect of the element on the constitutional changes in the alloy when cooled from a high temperature, including its effect on the condition of the carbon; and (c) the effect of the element on the structure and properties of the alloy.

The elements copper and arsenic are comparatively rare in cast iron. The use of alloys such as nickel, chromium, vanadium and others while increasing each year, is by no means common as yet. Hence we will confine our discussion to the four common elements which occur in various percentages in all cast iron: i. e., silicon, sulphur, phosphorus and manganese.

The Amount of Silicon in Cast Iron and the Control of this Element

In commercial cast iron the silicon varies from approximately 0.50 per cent to 3.25 per cent[96]. In pig iron to be used in the basic open-hearth process the silicon content should be below 1.00 per cent. For the acid open-hearth and acid Bessemer process the silicon may range from 1.00 per cent to as much as 3.00 per cent. Foundry irons are ordinarily graded according to silicon content; grade No. 1 contains 3.00 per cent, the percentage then decreases until in the case of grade No. 4 the iron contains only 1.50 per cent.

The silicon in the iron is the result of the reduction of the silica (SiO_2) in the ore by coke, in the blast furnace. The reducing reaction is

$$SiO_2 + 2C \rightarrow Si + 2CO$$
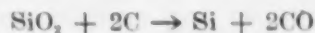
or according to some

$$SiO_2 + 2C + Fe \rightarrow FeSi + 2CO$$
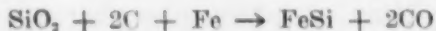
and proceeds rapidly only above a certain critical temperature and when the slag is not too strongly basic.

Iron ore contains between 5 and 30 per cent earthy matter, or gangue as it is called. A large percentage of this gangue is some

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[96]Irons containing higher percentages are usually classed as ferrosilicon.

form of silica. There is also silica in the ash of the coke and in the limestone which, together with the ore, make up the blast furnace burden. In smelting the ore in the blast furnace most of the silica is fluxed by the calcium oxide in the limestone and goes into the slag. A variable small amount is reduced by the above reaction and goes into the iron. As the reducing reaction depends upon the temperature in the furnace and the chemical composition of the slag, it follows that the furnace operator is able to control, to a certain degree at least, the amount of silicon reduced from its oxide.

In commercial practice an iron containing a relatively high percentage of silicon is produced when:

(1) The furnace temperature is high and the slag is normal; and when (2) the furnace temperature is normal and the slag is deficient in bases (calcium oxide); and an iron containing a relatively small percentage of silicon is produced when; (1) the furnace temperature is normal and the slag is very basic; and when (2) the furnace temperature is cold and the slag is normal.

We will see in a few moments that these operative conditions for the control of silicon are complicated further by those necessary for the control of the sulphur content. It should be understood that the four variables entering into the control of the silicon are not hard and fast rules; they are only generalizations that hold approximately. In practice it is necessary to take other factors such as slag viscosity and the like into account as well.

The Effect of Silicon on the Constitutional Changes, Structure and Properties of Cast Iron

In cast iron, as in steel, the silicon present combines with some of the iron to form iron silicide, FeSi, which dissolves in the rest of the iron. At atmospheric temperature the iron silicide is in solid solution in the ferrite. As is characteristic with constituents in solid solution, silicon in cast iron cannot be detected by the microscope, although Sauveur mentions that ferrite containing silicon in solution etches more slowly than pure ferrite.

In a previous chapter we saw that the eutectic in the pure iron-carbon alloys is 4.30 per cent carbon. According to Sauveur[97] who cites the work of Wüst and Peterson, each 1.00 per cent silicon lowers the carbon percentage of the eutectic by 0.30 per cent. For

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[97]Metallography and Heat Treatment of Iron and Steel, 1926, p. 374.

example, in a 2.50 per cent silicon cast iron the eutectic would be 3.55 per cent carbon instead of the 4.30 per cent.

The effect of silicon on the percentage of carbon in the eutectic alloy is shown graphically in Fig. 61, from Sauveur. The line AB divides the cast iron series into hypo- and hypereutectic alloys according to the percentages of carbon and silicon. For example, a cast iron containing 4.00 per cent carbon and 0.50 per cent silicon
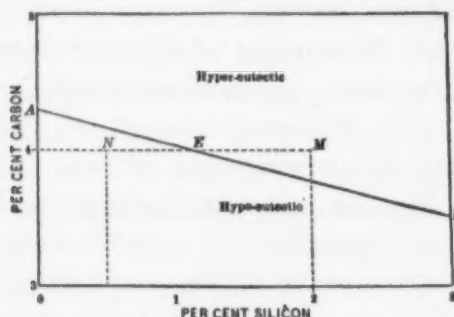
Fig. 61—Effect of Silicon on the Percentage of Carbon in Eutectic Cast Iron. (Sauveur.)

is hypoeutectic, point N, Fig. 61. On the other hand, if the cast iron contains 4.00 per cent carbon and 2.00 per cent silicon it is hypereutectic, point M, Fig. 61.

Silicon is active in promoting the formations of graphite. If other conditions are constant a cast iron containing a relatively high percentage of silicon will contain most of its carbon in the form of graphite. Rapid cooling opposes this tendency of silicon to promote graphite formation and causes the graphitization that does take place to result in particles of smaller size. As silicon reduces the carbon percentage, in the eutectic and as it is active in promoting graphite formation, it follows that this element will have a great effect on the properties and structure of cast irons.

It has already been noted that the properties of cast iron depend upon the composition of the matrix and the size and distribution of the graphite particles. In the last installment we discussed this, and saw that theoretically, a cast iron of maximum strength would have a matrix corresponding closely to the eutectoid, or about 0.80 per cent combined carbon, and would have the graphite particles as small and as uniformly distributed as possible.

Silicon and rate of cooling are the important factors in producing a cast iron of superior properties. With 2.00 to 3.00 per

cent of silicon the eutectic ratio is reduced to about 3.50 per cent carbon. As most commercial cast irons contain about this percentage of carbon, it follows that when 2.00 to 2.50 per cent silicon is present the iron will consist wholly of eutectic and will solidify at a constant temperature. It is known that the graphite particles are smaller when solidification is more rapid as is the case when it occurs at a constant temperature. A relatively high silicon percentage and fairly fast cooling will result in a cast iron having a matrix containing between 0.60 and 0.80 per cent combined carbon and containing the graphite in small and well distributed particles.

Figs. 62 to 67 show the structure of a cast iron of excellent properties. These specimens were taken from a piston ring for a Liberty aircraft engine. The iron had the following composition:

	Per Cent
Total Carbon	3.60
Graphite	2.97
Combined Carbon	0.63
Silicon	2.62
Sulphur	0.057
Phosphorus	0.461
Manganese	0.61

In the case of this particular iron, the composition is approximately that of the eutectic, due to the high silicon content. The method of casting piston rings is such that aided by the high silicon the combined carbon is desirably high and the graphite will be distributed in small particles, as is shown in Figs. 62 and 63. In Fig. 62 the graphite flakes are so small that they can scarcely be seen at a magnification of 100 diameters. The appearance of the individual flakes is shown in Fig. 63. Figs. 64, 65 and 66 show this specimen after etching. It will be noted that a magnification of 1000 diameters is necessary to resolve the laminated structure of the pearlite matrix (Fig. 66).

The Amount of Sulphur in Cast Iron and the Control of this Element

As sulphur is an undesirable impurity in cast iron as well as in steel, the percentage of this element is always kept as low as is possible in commercial practice. In first class irons for steel making, the sulphur content is nearly always maintained at 0.050 per cent or below; foundry irons poured into commercial castings may
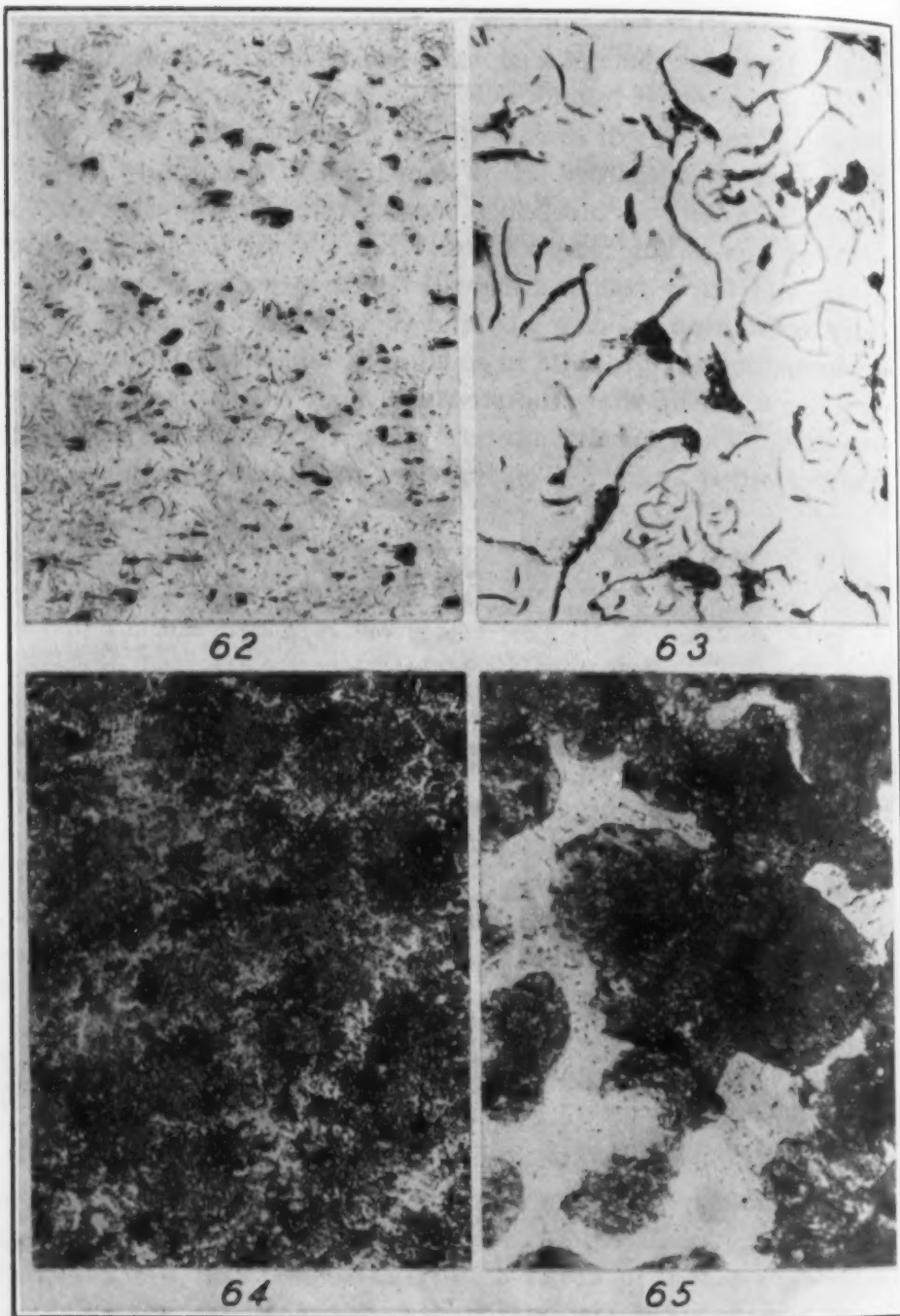
PHOTOMICROGRAPHS OF CAST IRON

Fig. 62—Cast Iron Piston Ring. Unetched, Showing Distribution of Fine Graphite Flakes. 100 x. Fig. 63—Cast Iron Piston Ring. Unetched, Same as Fig. 62 at Higher Magnification. 500 x. Fig. 64—Cast Iron Piston Ring. Etched Deeply with Alcoholic Nitric Acid. Granular Pearlite (Dark) and Phosphorus Eutectic (Light). 100 x. Fig. 65—Cast Iron Piston Ring. Etched Deeply with Alcoholic Nitric Acid. Same as Fig. 64 at High Magnification. 1000 x.

contain up to 0.150 per cent, but usually are below 0.100 per cent.

Of the raw materials making up the blast furnace burden, only the coke contains sulphur, very generally the iron ore and limestone are free from all but traces of this element.

Like silicon, sulphur may be partially controlled by the blast furnace operator. At a high temperature and in the presence of carbon, sulphur and calcium oxide react according to the reaction.

$$CaO + FeS + C \rightarrow CaS + CO + Fe$$

The calcium sulphide formed is soluble in a basic, fluid slag. Consequently, if temperature and slag conditions are correct, a large proportion of the sulphur will pass into the slag and remain there.

Under normal operating conditions the iron will have a low sulphur content (0.050 per cent or below) when; (1) the furnace temperature is very high and slag is normal; and when (2) the furnace temperature is normal and the slag is very basic; and the iron will have a high sulphur content (0.060 per cent or above) when; (1) the furnace temperature is normal and the slag deficient in bases; and when (2) the furnace temperature is cold and the slag normal. As in the case of silicon, these requirements for the control of sulphur are at best only generalizations and not rigid rules.

If we glance back over furnace conditions necessary for the control of silicon, we see that by the proper furnace operation we can control both silicon and sulphur. This has been discussed in detail in a former series of articles[98].

In normal blast furnace practice it is possible to produce an iron having a low silicon and low sulphur content, or a high silicon and high sulphur content; but in general, a high silicon content is accompanied by a relatively low sulphur content, and a low silicon by a relatively high sulphur content.

THE EFFECT OF SULPHUR ON THE CONSTITUTIONAL CHANGES, STRUCTURE AND PROPERTIES OF CAST IRON

Sulphur as an impurity in steel has been discussed in a previous installment. Most of the things said in regard to sulphur in steel, also hold true for this element in the cast iron series. These might

[98]See "On the Metallurgy of Iron and Steel", A. S. S. T., Preprint No. 1, p. 120; also TRANSACTIONS, Vol. 7, March, 1925, p. 370.

be repeated briefly. When no manganese is present sulphur com bines with the iron to form iron sulphide. This constituent melts at a temperature much below the melting point of the iron, hence in the solidification of the iron it tends to collect at the grain boundries destroying the cohesion of the grains and making the material brittle. At high temperatures iron containing iron sulphide will be brittle or "red-short". Red-shortness is not so dangerous in iron as in steel because ordinarily cast iron cannot be hot worked.

When manganese is present as is the case in practically all commercial cast irons, the sulphur combines with the manganese to form manganese sulphide. Manganese sulphide occurs in cast iron as rounded grayish areas readily visible under the microscope. The appearance of manganese sulphide in cast iron is so similar to this constituent in a cast steel specimen that no further description is necessary.

Sulphur is commonly spoken of as a hardening element in iron. There is no doubt but that it opposes the formation of graphite. Some investigators suggest that some iron sulphide is probably present and that this constituent is soluble in the cemen tite increasing its stability.

THE AMOUNT OF PHOSPHORUS IN CAST IRON AND THE CONTROL OF THIS ELEMENT

The amount of phosphorus in commercial cast irons varies widely. All of the phosphorus in the iron ore, coke and limestone is reduced by carbon in the blast furnace according to the reaction:

$$P_2O_5 + 5C + 6Fe \rightarrow 2Fe_3P + 5CO$$
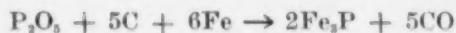
and goes directly into the iron. The furnaceman has no control over the above reducing reaction, hence in order to control the percentage of phosphorus in the iron it is necessary to control the raw materials making up the furnace burden. There is little, if any, phosphorus in the coke and limestone, consequently phosphorus control depends upon the choice of iron ores.

It takes approximately two tons of iron ore to produce one ton of pig iron, hence in round numbers the iron will contain twice as much phosphorus as the ore. Iron ores in the United States contain from a trace to 0.500 per cent phosphorus. In general the ores

which contain less than 0.040 per cent phosphorus command a premium in price over the higher phosphorus ore.

Iron is often graded according to phosphorus content; those special irons used for recarburizing in electric steel manufacture contain less than 0.040 per cent phosphorus; pig iron to be converted into acid Bessemer steel or acid open-hearth contains less than 0.080 per cent. For the basic open-hearth process where most of the phosphorus is removed in refining the iron normally contains 0.150 to 0.400 per cent of the element, although in some sections of the country—the Birmingham district especially—basic iron contains up to 0.800 per cent phosphorus. Foundry irons vary widely in phosphorus content; usually ranging from 0.100 to 0.800 per cent, sometimes more.

The Effect of Phosphorus on the Constitutional Changes, Structure and Properties of Cast Iron

When we discussed the occurrence and effect of the various impurities in steel, we saw that phosphorus, in the small amounts normally present in steel, combines with some of the iron to form iron phosphide which goes into solid solution in the ferrite. This is the case when the phosphorus is 0.200 per cent or below and the carbon is below 1.50 per cent as is the case in commercial steels. In cast iron where we often have more than 0.200 per cent phosphorus and nearly always more than 1.50 per cent carbon the phosphorus exists in another form.

In the presence of considerable carbon the phosphorus is thrown out of solution and, according to Stead, forms a ternary eutectic of 91.2 per cent iron, 6.9 per cent phosphorus and 1.9 per cent carbon. Stead has investigated this eutectic and has been able to identify it metallographically by heat tinting. Stead's work shows that this ternary eutectic is formed only in white and mottled cast iron; in gray iron and in the presence of considerable carbon a binary eutectic of iron phosphide and iron forms. This investigator claims that the formation of the binary eutectic of Fe_3P and iron is due to the diffusion of carbon out of the ternary eutectic of Fe_3P, iron, and carbon. The binary eutectic contains approximately 10 per cent phosphorus and 90 per cent iron and in honor of its discoverer is called "steadite".
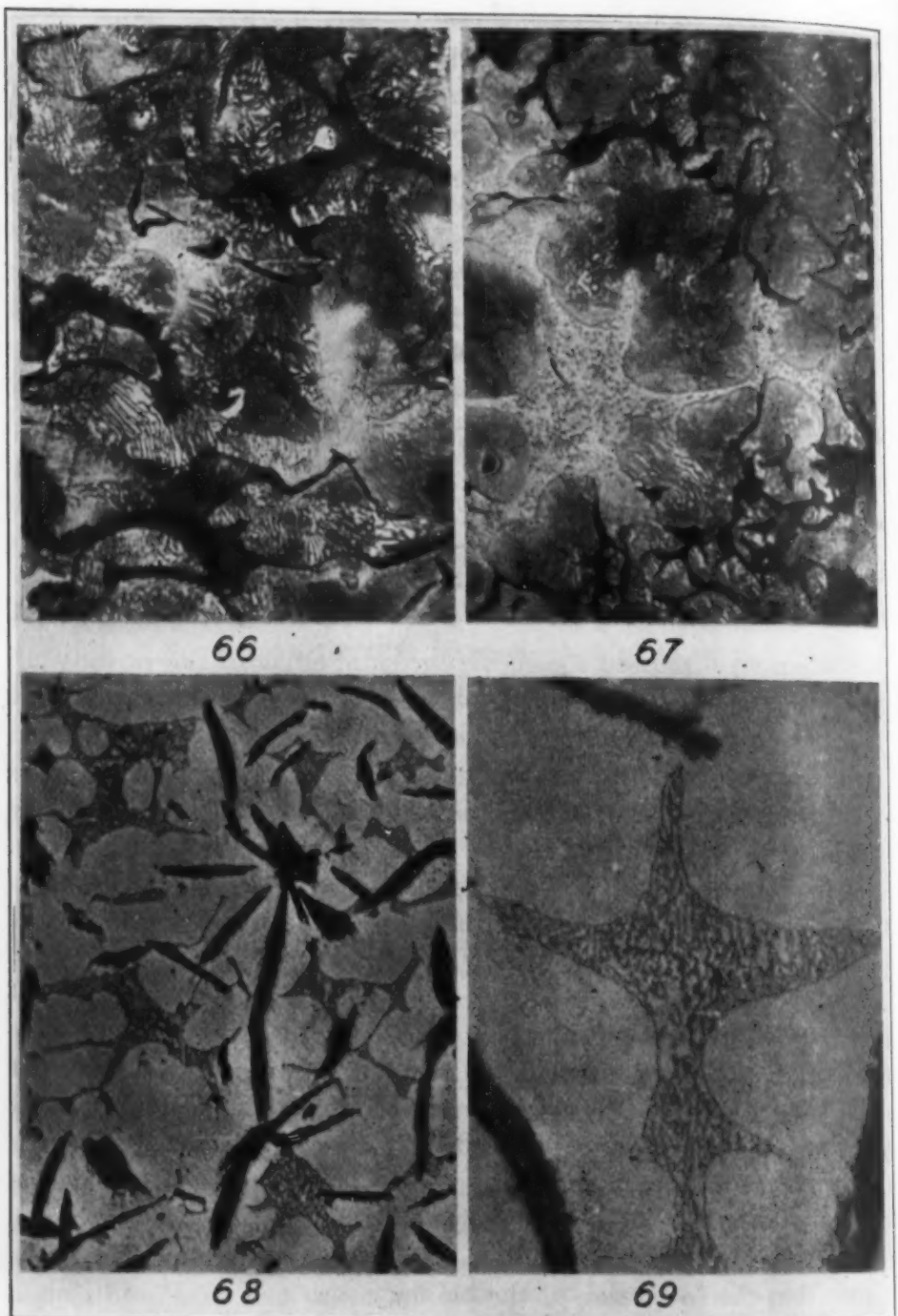
PHOTOMICROGRAPHS OF CAST IRON

Fig. 66—Cast Iron Piston Ring. Etched Lightly with Alcoholic Nitric Acid. Laminated Pearlite, Granular Pearlite (Dark), Graphite (Black), and Phosphorus Eutectic (Light). 1000 x. Fig. 67—Cast Iron Piston Ring. Etched Lightly with Alcoholic Nitric Acid. Showing Appearance of Phosphorus Eutectic (Mottled). 1000 x. Fig. 68—Cast Iron. Graphitic Carbon 3.06 Per Cent, Combined Carbon 0.08 Per Cent, Phosphorus 1.36 Per Cent. Magnification 100 x. Phosphorus Eutectic (Mottled) Graphite Flakes (Black), Matrix of Ferrite (Light). (Sauveur.) Fig. 69—Cast Iron. Same as Fig. 68 But Magnified 425 Diameters, Showing Detail of Phosphorus Eutectic.

The appearance of the binary eutectic of iron phosphide is shown in Figs. 67, 68 and 69. Fig. 67 shows the slightly mottled appearance of the eutectic. After continued etching it has a pitted appearance similar to that shown in Fig. 65. The phosphorus in the cast iron piston ring shown in Figs. 65 and 67 is 0.461 per cent. Figs. 68 and 69 from Sauveur[99] show the structure of a gray iron containing 1.36 per cent phosphorus. Fig. 69 shows the distinctly mottled appearance of the eutectic.

Stead has found in his researches that the tendency of carbon to expel the iron phosphide from solid solution is so great in the case of cast irons, that all of the phosphorus is expelled. The result is that the binary eutectic can usually be identified with the microscope even though there is less than 0.100 per cent present.

Phosphorus is commonly supposed to be responsible for brittleness. This is not wholly true unless the phosphorus is above 1.7 per cent, which is rare in commercial cast irons. In examining microsections it will be noted that in general the eutectic occurs in more or less isolated areas (See Figs. 68 and 69); in no case does it seem to form a network around the grains, a factor conducive to brittleness.

Phosphorus has no effect on the condition of the carbon. It does, however, make cast iron more fluid. This increased fluidity is probably due to the low melting point of the eutectic. Advantage is taken of the increased fluidity of phosphoretic iron in the pouring of ornamental iron castings of thin section. The ornamental cast iron fences and gates common a decade or so ago were poured from a high phosphorus iron.

THE AMOUNT OF MANGANESE IN CAST IRON AND THE CONTROL OF THIS ELEMENT

Manganese as manganese oxide is found in most iron ores. Unless present in large amounts, all of this constituent is reduced by carbon in the blast furnace according to the reaction

$$MnO_2 + C \rightarrow Mn + CO_2$$
$$MnO_2 + 2C \rightarrow Mn + 2CO$$
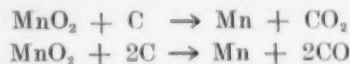
and goes into the iron. As in steel the manganese combines with the sulphur to form manganese sulphide, MnS. When more man-

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[99]Metallography and Heat Treatment of Iron and Steel, 1926, p. 386.

Acid. Laminated
utectic (Light).
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68—Cast Iron.
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ganese is present than is necessary to combine with the sulphur, as is always the case in commercial irons, the rest combines with the carbon to form manganese carbide Mn_3C. The manganese carbide together with iron carbide forms cementite.

The percentage of manganese in commercial cast irons ranges from about 0.25 per cent to 2.00 per cent or more. Iron-manganese alloys containing 10 to 20 per cent manganese are known as spiegel-eisen and the alloys containing 60 to 85 per cent manganese as ferromanganese. The spiegeleisen and ferro-alloys are used to introduce manganese into the molten bath in the various steel making processes.

Like phosphorus, manganese is not under the control of the furnace operator. In order to control the amount of manganese in the iron he must choose ores containing the right proportions of this element.

The Effect of Manganese on the Constitutional Changes, Structure and Properties of Cast Iron

The greatest effect of manganese on cast iron is that it combines with the sulphur to form the relatively harmless impurity manganese sulphide, instead of the extremely fusible and harmful iron sulphide. This has been discussed in a previous installment on the effect of impurities in steel.

Manganese is generally supposed to oppose the formation of graphite. Like sulphur it acts as a hardener to iron, in large amounts it makes castings difficult to machine. Manganese carbide is thought to be more stable than iron carbide and is supposed to increase the stability of the cementite, thus opposing the formation of graphite.

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MODERN FURNACES AND HEAT TREATING METHODS

By E. F. Davis

Abstract

*The author of this paper has described and dis-
cussed in a practical way the various methods which are
in use in many manufactories in the heating of steel
parts for forging, hardening and tempering. He makes
a plea for a more thorough study of the problems of
the average heat treatment departments whereby these
departments may be provided with more efficient heat-
ing equipment. A comparison is made of the type of
high production machining equipment which is provided
for most machine shops in contrast to the antiquated
inefficient heating equipment found in many of the so-
called modern plants.*

*A discussion of the merits of the different methods
and types of furnaces used in heating metal parts is
dealt with at length.*

IN the development of quality parts in production quantities,
we have gone about it in much the same fashion of the small
boy who, about to make a drawing of a house, started with the
most obvious thing to him—the smoke coming out of the chimney.
The maintaining of close-size uniformity has been the most ob-
vious thing in production duplication and most of the attention
has been concentrated toward producing pieces in quantities at
low cost, and at the same time, holding sizes in close accuracy.
The micrometer, Johansson gages, and other precision tools were
in common use when heat treating was practiced in much the
same way as in the days of Tubal Cain. In other words, much
progress has been made in machining operations and accuracy
of size so that the part will fit as a member in an assembled unit
and will function mechanically, but not enough has been done
toward improving the inherent qualities of the metal. Formerly
this may not have been necessary because the parts were designed
with high factors of safety and metal mass compensated for the

defects of inferior heat treating practice. But now with the demand for lighter sections and correspondingly lower factors of safety the need for better heat treating methods becomes urgent.

Many Heat Treating Plants Inadequate

Today, many heat treating departments in otherwise modernly equipped organizations, are shamefully neglected units. Go into many plants and after marveling at the phases of fabricating efficiency, visit the heat treating department. A place of smoke and grime, dirt floors, men operating inefficiently and laboriously, badly constructed furnaces, fuel wastage, poor pyrometric equipment. Why does such a condition exist? Why will a management balk at paying $5000 for a modern furnace, but will spend it readily for a machine which will increase production 20 per cent on one part. Is not a dollar saved in the heat treating department as good as a dollar saved in the machine lines? Sometimes I believe it is because the heat treating department lacks champions. Many factory executives have risen to positions of responsibility from the shop, and with their thought and energy always concentrated upon the mechanical problems of production they have failed to fully realize the possibilities which lie dormant in improving heat treating operations. Why does it cost 9 to 12 cents per pound to carburize? It can be done for 6 cents per pound. The installation of a modern annealing furnace in one plant eliminated the labor of nine men, saved $500 a month on the gas consumption, and reduced furnace repairs $2400 per year. Not only will efficient heat treating equipment return dollars to the coffers, but it also has indirect benefits affecting the machinery departments. For example, let us consider the steel used in producing a given piece of equipment.

The Inherent Properties of Steel

Within this steel is a microscopic constituent known as pearlite, consisting of about 87 per cent pure iron and 13 per cent of an iron-carbon compound known as cementite. This constituent occurs in many shapes and modifications, nine of which are recognized by metallurgists. These variant forms of pearlite have a tremendous effect upon profits. That torn hole which caused

the piece to be scrapped. The parts which jammed on the broach and broke a $50 tool. That lot of steel which drilled so roughly. Those forgings which broke so many taps. The trouble the operator had in holding his sizes when turning that shafting. These troubles were all caused by improper pearlitic structure which is easily within our control by proper heat treatment. In some steels the pearlite must be globular or spheroidized for the best cutting conditions. In others, it must be striated or lamellar for maximum machinability. Yet either form can be produced at will by proper heat treating practice. The scleroscope and Brinell tests will reveal the presence or absence of another modification called sorbitic pearlite. This may be distinguished from normal pearlite by being of greater density and hardness and therefore offering greater resistance to tooling operations. But the other seven modifications are not distinguished by hardness testing. This is the reason that two pieces of steel of the same Brinell reading often show wide differences in machining qualities.

To produce steel having the desired form of pearlite and duplicate it day after day just like production parts are duplicated in dimensional sizes, certain unvarying cycles of heating and cooling are essential. Intelligently designed equipment must be used. Continuous furnaces for annealing are always advisable if the production warrants such an installation, because these are capable of maintaining a fixed cycle and with automatic control these furnaces can be operated with mechanical precision.

BATCH ANNEALING

By batch annealing in stationary furnaces, uniformity is impossible. Forgings in the center of the pile will heat more slowly and cool slower than those on the outside. Since pearlite spheroidizes by slow cooling, and remains lamellar or sorbitic when cooled with fair rapidity, it can readily be seen, that all kinds of steel structures will follow. It is possible, however, to obtain fair results even with stationary furnaces if the forgings are not piled. But this, of course, reduces the quantity per heat.

Underfired furnaces should always be used for annealing alloy and high carbon steels. Overfired furnaces will not produce uniform temperatures in the furnace due to the very principle of overfiring. The writer realizes that in making this statement

that many overfired furnace installations may be found in different plants, but makes the statement because of all those furnaces that he has examined have the same common defects; namely, cold floors, flame impinging on the work, hot and cold areas and a general lack of uniformity. Underfired furnaces provide a hot hearth, hot side walls and hot arch and uniform radiance. Most annealing furnaces are gas or oil-fired but many of the newer installations are using the electric elements. Electric heat is ideal for nearly all annealing operations. The chief objection is the high initial cost of these installations.

Heating Steel for Hardening

In heating steel for hardening or tempering, four methods are in common practice, namely, heating by immersion in a liquid or molten medium; by direct radiation of the heat to the work; by conveying the heat directly to the work by flame or combustion blast; and by transferring the heat by an air blast previously heated.

Immersion Method of Heating

Immersion heating would include such mediums as oil, lead, molten salts, such as saltpetre, cyanide, soda ash, barium chloride, etc.; radiant heating by the various types of electric furnaces now in common use; heating with flame or combustion products, forge and billet furnaces, and the many varieties of oil and gas furnaces employed in hardening.

Immersion heating has the advantage that no section of the work being treated can become hotter than the medium in which it is immersed. All liquids increase in mobility when heat is applied. The hotter portion ascends due to lighter gravity, and reaching the top loses a certain amount of its heat by radiation. This constant boiling action serves to keep the liquid surprisingly uniform in temperature throughout its mass, and temperature variations are negligible. For this reason immersion heating possesses many advantages when close temperatures are pre-requisite.

Immersion heat treating can be used for all ranges of temperatures from 250 to 2200 degrees Fahr. The temperatures from 250 to 1250 degrees Fahr. may be regarded as the annealing or tempering ranges. Oil or nitrites are suitable up to 600 degrees Fahr.; saltpetre from 600 to 1000 degrees Fahr.; and lead above

1000 degrees Fahr. For tempering, oil or nitrites are the best mediums and should be employed in preference to air tempering furnaces. Radiation air tempering furnaces are not suitable for temperature ranges below 900 degrees Fahr. if exact temperatures are required. This is due to the sluggish heat exchange and the impossibility of obtaining uniformity in a furnace of the size necessary for production quantities and economical operation. For economy, oil, as an immersion medium, is preferable to nitrites or tempering salts. A good tempering oil can be purchased for around 30 cents per gallon. A price of 12 to 14 cents for tempering salts does not seem to be excessive until one considers that the salt is used in the molten state and that a gallon of molten nitrite salt costs from $1.50 to $2.50. Electric heating of oil tempering furnaces is preferable to gas or oil for it reduces the fire hazard and practically eliminates it if the electric units are sheathed and the units never exposed to oil vapors. With additional electrical control, temperatures can be held within a limit of 10 degrees and such furnaces can be placed in progressive production lines.

The writer designed and had constructed a continuous furnace of this type which is used in daily operation in his plant. This particular furnace eliminated one man, took the human element and consequental variables out of the operation and the furnace has never given a moment's trouble since its installation a year ago. A small fust of lead alloy is immersed in the oil. If for some reason the control would fail to function and the oil reach a temperature near its flash point, the fust would melt and break the current.

Immersion Heating for Hardening

For hardening, by immersion, lead and cyanide mixtures are the most common mediums in use. Lead is not suitable for temperatures above 1600 degrees Fahr. due to the rapid oxidation of the lead, causing deterioration in the quality of the metal and developing considerable vapor pressure of these exceedingly poisonous fumes. Cyanides decompose rapidly above 1600 degrees Fahr, and at 1800 degrees Fahr., barium chloride should be used if slight decarburization of the surface is not detrimental. So far, immersion methods above 1800 degrees Fahr. have not met with

a great degree of success due to the inability to produce pots which will give satisfactory long life, and the difficulty of designing furnaces with ample heat capacity. These have also caused further troubles where only 500-B. t. u. gas is available. It will be remembered that immersion heating is done indirectly and that the salt is kept molten entirely by the heat radiation through the pot walls. To maintain a temperature of around 1800 degrees Fahr. in the immersion salt means that considerably higher temperatures must be maintained in the combustion chamber. If considerable production is expected, it means that a temperature of nearly 2800 degrees Fahr. must be held in the combustion chamber. At this heat, firebrick softens and the best alloy pots will deteriorate very rapidly. Pressed steel and cast steel pots are the most economical for molten salts. Alloy pots are superior for molten lead.

Cyanides produce the cleanest work of any of the molten mediums. They are solvents for oxides and except for a gray cyanide stain, work comes out of cyanide as clean as it enters. When cyanides are employed a 40 per cent mixture of cyanide with 60 per cent soda ash is satisfactory. This mixture costs about 10 cents per pound. It melts around 1250 degrees Fahr. and is available for heat treating operations at 1350 degrees Fahr. or higher. This should contain at all times between 25 and 30 per cent sodium cyanide. When it falls below 20 per cent a slight decarburizing effect occurs on the work being hardened. When the cyanide content is below 25 per cent a slight pinkish tinge is evident in the solidified salt. Common salt is sometimes used in cyanide mixtures for hardening but the salt fumes cause excessive rusting of the steel girders and everything else of iron and steel in the heat treating department.

The author does not recommend electric heating for cyanide immersion hardening, for several reasons. First, the operating costs are excessive; second, the installation costs are too high compared with gas and oil furnaces and last, there is always danger of burning out the unit by accidental spillage of cyanide. These molten salts are electrical conductors and will produce a short circuit in the elements. It is true that some successfully operating furnaces are in use today but nevertheless this danger is always present unless the design is such that no cyanide can pos-

sibly come in contact with the heating elements. Even though this is provided against, nothing is gained by employing electric energy for heat. The heat is radiated from the elements to the pot. Then the heat must be radiated through the pot walls to the salt. In continuous production work, these elements would have to maintain excessively high temperatures which would shorten their life. It is obvious, therefore, that such furnaces could not be cheaply operated. Gas or oil furnaces are preferable. The author's company built a 2-pot gas-operated cyanide furnace for $500. The same furnace, electrically heated, would have cost $5000.

For heat treating operations between 1400 and 1600 degrees Fahr. the electric furnace comes within its widest field of usefulness, because the radiation principle of heat transfer is most effective within these ranges. With electric elements for heating and electrical control, any desired temperatures can be regulated within narrow units. Electric control may be regarded as the micrometer of heat treating and is absolutely necessary for uniform hardening. Electric heat treating furnaces may be made automatic and continuous, or both, and a standardized time and temperature cycle maintained, with every piece receiving exactly the same treatment and eliminating the variables incidental to the human factor.

With open elements, the furnaces may be fast heating or with insulated elements they may be designed to heat as slowly as desired. A thermal efficiency of 50 to 75 per cent is possible in some types of furnaces. Temperatures between 1400 and 1600 degrees Fahr. are not severe on electric units and many types of heating elements will give a life of 3 to 4 years, and some even longer. The neutral atmosphere of these furnaces and absence of oxidizing blasts reduces scaling to a minimum.

HEATING FOR CARBURIZING

For carburizing, the present designs of electric furnace are not as economical as the gas or oil-fired furnace although some very successful installations are being used of the horizontal rotary hearth-type, and even of the stationary type. But the carburizing operation is a fuel waster because the majority of the available B. t. u.s are consumed in penetrating the heavy walls of

the boxes and heating through the slow conducting carbonaceous material which is most resistant below the temperatures at which it imparts any carburizing action to the steel. Furthermore, the carburizing material makes up three times the volume of the steel to be carburized. The carburizing of steel to a depth of 0.035 inch requires about 2 hours, but 4 to 10 hours are consumed in addition in heating the boxes and carburizing material to the active carburizing temperature.

Since electrical heat shows economy only where it is not wasted but held within the furnace by insulating mediums, it is very doubtful that electrically heated carburizing furnaces of present design will show any economy if the fuel alone is considered. But for exact temperatures, a vital thing in carburizing, the electric fuel is superior. Furthermore, the fuel represents only about 4 per cent of the process cost. Pots and lids make up 15 per cent of the cost, the carburizer 30 per cent, furnace depreciation 4 per cent and labor 45 per cent.

The carburizing operation is still in a very crude state. The process is expensive and laborious and the writer looks for much development in more efficient methods within the next few years. Elimination of carburizing boxes, solid carburizers and reduction of labor costs is the solution. The most advanced improvement in furnace efficiency and labor reduction is the counterflow continuous type. Generally speaking, this consists of a series of conveyors, each alternate one traveling in opposite directions. The furnace is loaded and unloaded at both ends so that the boxes entering the furnace are heated by those coming out at the same door. This heat exchange saves the wastage of fuel from the usual method of removing the hot boxes directly and allowing them to cool in the air with all the heat dissipated and lost. All of these furnaces are reported to have shown excellent fuel economy and reduced labor costs. The advisability of purchasing such a furnace is governed by production volume, because continuous furnaces of any kind must be operated fully loaded and without frequent shutting down to show economy. It costs from $20 to $25 to bring one of these furnaces to the operating temperature.

HEATING TOOLS FOR HARDENING

Electric furnaces, for tool work, have been a boon for the

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manufacturer of small tools such as taps, drills, dies, etc. Several designs are in use. The crucible-type, the ordinary muffle-type and the continuous-type for production tool hardening. The hardening of tools is a vital operation and temperatures must be kept in close control if satisfactory life is to be obtained from the tool. The rate of heating is also of utmost importance. It is annoying, to say the least, to have a tool on which $60 in labor had been expended, crack during heat treatment due to too fast heating or improper hardening temperatures. Incidentally, it may be remarked, that more tools crack in hardening due to quenching the steel too near the critical point than hardening at too high a temperature. The reason for this is that steel at its critical temperature is in a state of contraction, whereas steel above the critical point, or below it, is in a state of expansion. The center of the metal mass is always cooler than the outside, hence if the steel is heated too rapidly and is quenched only a few degrees above its critical temperature, the inside mass is still in the critical range and unusual strains are set up which promote cracking. The same condition would ensue if a wide variation exists between the outside and the inside of the mass, even if the hardening is done well above the critical range, for in passing down through the critical temperatures, these same strains may be set up. Nearly all electric furnaces heat by radiation and the heating chambers are small, hence the heating rate is slow and the tool is given ample time to heat uniformly. The freedom from oxidation is also an advantage of electric furnace tool hardening, because the work comes out nearly free from scale. Highly reducing atmospheres, however, should be avoided for this produces a soft skin on the work.

When electric furnace installations are used, the hardening can be done directly in the tool room for no gas and air lines need to be laid, no objectionable furnace gases permeate the department and the room temperature desired in this department can be maintained. Hardening in the tool room is always an advantage for the hardener, who by daily contact with the toolmakers, becomes more familiar with the functions of specific tools and can consult with the tool room foreman whenever he is in doubt of what is wanted. On the other hand, if the tool hardening is far removed from the tool room, this intimate contact

is lost and costly mistakes are sometimes made due to the unfamiliarity of the hardener with the requirements of the tool.

First class tool hardeners can harden equally as well in gas or oil furnaces. Many plants educate their own men and do not employ experts, which is as it should be. It is cheaper in the long run to provide the best equipment rather than pay high wages in order to successfully operate poor equipment.

High Speed Steel Hardening

For high speed steel hardening, gas or oil furnaces are mostly used. Forged tools are often hardened in the direct blast of small point furnaces, and cutters and larger tools in small semi-muffle furnaces. Several types of electric furnaces for high speed steel hardening were tried out a number of years ago, but were failures and much prejudice exists today toward them. The principal objection to these earlier types was their slow heating rate. High speed steel must be heated very fast above its 1500-degree Fahr. preheat and must come up to 2350 degrees Fahr. in from 1 to $2\frac{1}{2}$ minutes. Slow heating to high temperatures produces that weak crystalline condition known as the fish scale fracture. Steel having this structure will not hold an edge and breaks easily in service. Furnaces of a new type have appeared recently which have overcome the faults of the earlier designs. These use a resistance element known as the "glow bar". These furnaces are still in the experimental stage. The principal objection to them seems to be the short life of the "glow bar," and the difficulty of maintaining a standard resistance. Another design of the carbon resistance-type has a series of carbon plates surrounding the heating chamber. These units must be renewed about every 12 to 14 days. This type is giving good satisfaction and the current consumption is low. Caution should be used in deciding upon electric heat for high speed steel heating furnaces, particularly in reference to the selection of reliable elements. The burning out of a unit during a high temperature heat might spoil a valuable tool. The furnace should be checked daily to be sure that the resistor elements are in good condition. Much work is necessary yet toward improving heating elements that are reliable above 2200 degrees Fahr. and will give longer life.

The faults of immersion heating furnaces for high speed steel have already been discussed.

HEATING FOR FORGING

Forge furnaces need much improvement. They depend upon direct blast for heating the bars and billets and overheating of steel is much too common. The amount of harm done is an uncertain variable. Raising the steel to a very high temperature decarburizes it, increases the grain size and weakens the intercrystalline cement. Forging decreases the grain size again and mitigates a portion of the evil. If much work is done in forging, the trouble is minimized; if little work is done, the grain size remains large. If a billet is heated to 2100 degrees Fahr. and finished at 1600 degrees Fahr. a good forging can be expected. If a billet is heated to 2350 degrees Fahr. and finishes at 2000 degrees Fahr. a poor forging will result. The effect of high forging temperatures is ruinous to steel quality. Overheated forgings are sluggish to thermal changes. They do not anneal readily. They do not harden satisfactorily, and are weak to impact and show a dry coarse fracture. The writer has seen bars pulled from forge furnaces for upsetting which actually fell in two from their own weight. With the necessity for better and more uniform heating, the forge plant must advance with other industries. Those who do not keep apace with modern requirements will some day be facing a receivership.

The stationary forge furnace is not only an unreliable heating medium but very inefficient. Probably not over 5 per cent of the fuel used is consumed in heating the steel, the other 95 per cent is wasted. The forge furnace can bring a piece of steel to the forging temperature in 6 minutes and burn or melt it in 10 minutes. Continuous furnaces are possible and practical in production forging operations. Several installations have already been made in some of the larger industrial plants. In designing a continuous furnace, slow heating should be provided up to 1700 degrees Fahr. and then rapid heating from 1700 to 2100 degrees Fahr., which is the usual forging temperature. Slow heating from 1700 to 2100 degrees Fahr. is dangerous, because the element of time enters into steel quality as well as temperature. Ten minutes at 2100 degrees Fahr. might do little harm

to steel beyond increasing the grain size but 30 minutes at 2100 degrees Fahr. might ruin it. It seems to me in accomplishing the time and temperature cycle necessary for good forging practice, that an electric furnace would accomplish this best. The small floor space necessary, the fuel economy of an insulated electric furnace, the reduction of scaling, and absence of decarburizing action, the maintaining of any desired speed of heating, the possibility of exact electric control, to say nothing of the elimination of oil tanks, pipe lines, pumps, air compressors, oil freezing in the winter, fire hazards, etc., would make the electric furnace very acceptable to the forging industry.

No doubt within a few years forging plants that are now making a real effort to control forging heats and improve their practice, will be advertising certified forgings and guaranteeing their forging and finishing temperatures.

Conclusion

The author realizes that he has only skimmed over the vast subject of heat treating but his object has been to show that the "acre of diamonds" exists in improving heat treating practice, and much opportunity lies dormant for the saving of dollars and cost reduction by the installation of modern equipment. In his own plant, every modern furnace which has been purchased or built, has improved heat treating quality by eliminating human variables and standardizing heating cycles. The financial side has been reflected by reduced labor and increased production. Electricity plays an important role in all these heat treating operations. The plant with which the writer is connected has 31 electric furnaces and a large continuous normalizing and annealing furnace which, although gas-fired, has the gas valves, the pushing mechanism, and the entire heating and cooling cycle under electrical control.

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THE IRON INDUSTRY IN 1926

IN magnitude of production in 1926 the iron and steel industry recorded a remarkable year, according to the United States Bureau of Mines, Department of Commerce. The production of steel in 1926 was the largest ever recorded and the production of pig iron was only 2 per cent less than the record year. The production of iron ore, however, did not keep pace with the outputs of steel and pig iron, it showing a decrease of about 10 per cent from the year of largest output.

Iron Ore. The iron ore mined in 1926 amounted to 67,623,000 gross tons, an increase of 9 per cent as compared with 1925. The shipments of iron ore in 1926 amounted to 69,292,832 gross tons, valued at \$174,015,645, an increase of 8 per cent in both quantity and total value as compared with 1925. The average value per ton of iron ore at the mines in 1926 was \$2.51, which is virtually the same as the average for 1925. The stocks of iron ore at the mines at the end of 1926 amounted to 9,495,880 gross tons compared with 10,795,630 tons at the end of 1925, a decrease of 12 per cent.

Iron ore mined in the United States, 1925-1926, in gross tons

(Exclusive of ore containing 5 per cent or more of manganese)

State	1925	1926	Percentage of increase or decrease in 1926
Alabama	7,093,250	6,847,789	— 3
California	352	282	— 20
Colorado	8,642	35,535	+311
Georgia	78,835	51,642	— 34
Michigan	14,490,529	15,248,254	+ 5
Minnesota	36,856,244	40,701,613	+ 10
Missouri	40,043	124,371	+211
Montana	3,672	724	— 80
New Jersey	202,942	209,117	+ 3
New Mexico	172,959	216,269	+ 25
New York	141,534	638,849	+351
North Carolina	22,011	15,198	— 31
Ohio	2,410	....	—100
Pennsylvania	955,955	1,095,505	+ 15
Tennessee	164,717	138,819	— 16
Utah	270,029	295,009	+ 9
Virginia	96,272	49,159	— 49
Washington	830	1,702	+105
Wisconsin	817,149	1,322,776	+ 62
Wyoming	489,622	630,387	+ 29
	61,907,997	67,623,000	+ 9

Iron ore mined in the United States, by mining districts and varieties, 1925-26, in gross tons

(Exclusive of ore containing 5 per cent or more of manganese)

District 1925	Hematite	Brown ore	Magnetite	Carbonate	Total	Percentage of increase or decrease in 1926
Lake Superior[a]	52,056,663	....	....	.....	52,056,663	....
Birmingham	6,312,207	323,599	....	.....	6,635,806	....
Chattanooga	259,843	96,877	....	.....	356,720	....
Adirondack } Northern New Jersey and southeastern New York }	....	....	328,745	.....	328,745	....
Other districts	[b] 917,977	[b] 464,124	1,143,259	4,703	2,530,063	....
	[b] 59,546,690	[b] 884,600	1,472,004	4,703	61,907,997	....

1926

Lake Superior[a]	57,143,407	....	....	.....	57,143,407	+ 10
Birmingham	6,114,917	393,300	....	.....	6,508,217	— 2
Chattanooga	198,574	68,550	....	.....	267,124	— 25
Adirondack						
Northern New Jersey and southeastern New York	....	....	[c] 847,966	.....	[c] 847,966	+158
Other districts	[bc] 1,177,675	[b] 349,074	1,327,322	2,215	[c] 2,856,286	+ 13
	[bc] 64,634,573	[b] 810,924	[c] 2,175,288	2,215	67,623,000	+ 9

[a]Includes only those mines in Wisconsin which are in the true Lake Superior district.
[b]Some hematite included with brown ore.
[c]Some hematite from "Other districts" included with magnetite from Adirondack district.

Iron ore shipped from mines in the United States, 1925-26, by States

(Exclusive of ore containing 5 per cent or more of manganese and of ore sold for paint)

State	1925		1926		Percentage of increase or decrease	
	Gross tons	Value	Gross tons	Value	Quantity	Value
Alabama	6,891,081	$14,134,677	6,871,421	$13,846,656	— 0.3	— 2
California	352	(a)	282	(a)	— 20	.....
Colorado	8,642	(a)	35,535	(a)	+311	.....
Georgia	79,488	231,683	51,642	149,198	— 35	— 36
Michigan	15,254,003	40,926,315	16,699,984	43,932,982	+ 9	+ 7
Minnesota	38,022,237	96,083,485	40,961,361	103,715,621	+ 8	+ 8
Missouri	40,043	(a)	124,371	532,536	+211	.....
Montana	3,672	10,244	724	1,810	— 80	— 82
New Jersey	164,523	678,021	212,152	925,403	+ 29	+ 36
New Mexico	172,959	(a)	216,269	(a)	+ 25	.....
New York	413,517	1,988,735	659,741	3,015,586	+ 60	+ 52
North Carolina	22,011	49,511	14,798	31,645	— 33	— 36
Ohio	2,410	(a)	....	....	—100	—100
Pennsylvania	917,255	2,149,800	1,088,634	2,483,056	+ 19	+ 16
Tennessee	164,073	369,144	138,307	312,109	— 16	— 15
Utah	268,529	361,251	296,943	411,611	+ 11	+ 14
Virginia	76,302	174,454	49,703	162,446	— 35	— 7
Washington	830	(a)	1,702	(a)	+105	.....
Wisconsin	953,214	2,260,388	1,238,885	3,178,156	+ 33	+ 41
Wyoming	489,622	(a)	630,387	(a)	+ 29	.....
Undistributed	....	[b]1,379,178	....	[b]1,316,830	.....	.....
	63,924,763	160,796,886	69,292,832	174,015,645	+ 8	+ 8

[a]Included under "Undistributed."
[b]This figure includes value for States entered at "(a)" above.

Pig Iron. The production of pig iron in 1926, exclusive of ferro-alloys, was 38,755,698 gross tons, compared with 36,124,678 tons in 1925. In the production of pig iron in 1926 there were used 65,922,601 gross tons of domestic iron ore and manganiferous iron ore; 2,442,631 tons of foreign iron ore and manganiferous iron ore; and 6,254,523 tons of cinder, scale, and scrap, a total of 74,619,755 tons. An average of 1.925 gross tons of metalliferous materials was consumed per ton of pig iron made in 1926, as compared with 1.924 tons in 1925.

The shipments of pig iron from blast furnaces in 1926, amounting to 38,181,053 gross tons, valued at $749,633,468, showed an increase of 3.7 per cent in quantity and 1.4 per cent in total value. The general average value of pig iron of all grades at the furnaces in 1926 was $19.63, a decrease of 45 cents from the value in 1925.

Pig iron shipped from blast furnaces in the United States, 1925-26, by States follows on the next page.

State	1925		1926		Percentage of increase or decrease	
	Gross tons	Value	Gross tons	Value	Quantity	Value
Alabama	2,910,370	$57,777,275	2,875,534	$58,119,260	— 1.2	+ 0.6
Colorado	(a)	(a)	(a)	(a)	.....	.....
Illinois	3,600,484	74,937,781	3,626,330	73,460,392	+ .7	— 2.0
Indiana	3,350,747	64,807,575	3,670,478	69,292,329	+ 9.5	+ 6.9
Kentucky	153,935	(a)	148,053	(a)	— 2.8	.....
Maryland	693,523	(a)	791,637	(a)	+ 14.1	.....
Massachusetts	....	....	23,130	(a)	.....	.....
Michigan	831,435	18,425,346	638,282	13,180,113	— 23.2	— 28.6
Minnesota	276,240	(a)	292,658	(a)	+ 5.9	.....
Missouri	3,758	(a)	....	....	—100.0	—100.0
New Jersey	(a)	(a)	(a)	(a)	.....	.....
New York	2,151,306	40,435,443	2,389,665	44,970,196	+ 11.1	+ 11.2
Ohio	8,857,615	173,418,068	9,177,127	176,433,401	+ 3.6	+ 1.7
Pennsylvania	12,537,809	258,140,674	13,142,528	263,238,184	+ 4.8	+ 2.0
Tennessee	95,186	2,014,176	113,029	2,544,825	+ 18.7	+ 26.3
Utah	126,746	(a)	(a)	(a)	.....	.....
Virginia	97,884	2,237,749	105,019	2,322,451	+ 7.3	+ 3.8
West Virginia	499,047	9,416,095	364,302	(a)	— 27.0	.....
Wisconsin	226,712	4,836,952	235,597	5,034,012	+ 3.9	+ 4.1
Undistributed	b 402,175	b32,842,199	b 587,684	b41,038,305	.....	.....
	36,814,702	739,316,333	38,181,053	749,633,468	+ 3.7	+ 1.4

ᵃIncluded under "Undistributed."
ᵇIncludes figures for States entered as "(a)" above.

Ferro-alloys. The shipments of ferro-alloys of all classes in 1926 amounted to 689,258 gross tons, valued at $61,368,407, an increase of 12 per cent in quantity and of 16 per cent in total value. The production of ferro-alloys in 1926 was 674,389 gross tons, as compared with 575,455 tons in 1925, an increase of 17 per cent.

The production of ferromanganese in 1926 was 318,052 gross tons, averaging 79.25 per cent of manganese, and containing 252,066 tons of manganese (metal). In the production of ferromanganese in 1926 there were used 619,-898 gross tons of foreign manganese ore, 36,309 tons of domestic manganese ore, 488 tons of domestic manganiferous iron ore, 7,576 tons of iron ore, and 5,122 tons of cinder, scale, and scrap. The quantity of manganese ore used per ton of ferromanganese made in 1926 was 2.063 gross tons; in 1925 it was 2.133 tons; and in 1924 it was 2.186 tons. Of the foreign manganese ore used in 1926, Russia supplied 282,954 gross tons; Brazil, 237,358 tons; Africa, 42,692 tons; India, 31,667 tons; and the remainder was from Cuba, Chile, and Porto Rico. The quantity of domestic manganese ore used in the manufacture of ferromanganese in 1926 represented only 5.5 per cent of the total manganese ore used.

The production of ferromolybdenum and calcium-molybdenum compounds in 1926 was 1,248 gross tons, containing 1,010,849 pounds of molybdenum (metal). The ferro-molybdenum averaged 58.43 per cent and the calcium-molybdenum compounds 34.54 per cent.

The production of ferrotungsten in 1926 was 1,808 gross tons, averaging 77.09 per cent of tungsten, and containing 3,121,928 pounds of tungsten (metal).

The production of ferrovanadium in 1926 was 1,962 gross tons, averaging 36.15 per cent of vanadium, and containing 1,588,591 pounds of vanadium (metal).

Ferro-alloys shipped from furnaces in the United States, 1925-26, are as follows on the next page.

Variety of alloy	1925 Gross tons	Value	1926 Gross tons	Value
Ferromanganese	} 245,005	$26,006,439	330,070	$31,711,871
Silico-manganese and silico-spiegeleisen	}		2,183	354,364
Spiegeleisen	95,890	2,407,226	82,982	2,016,088
Ferrosilicon (7 per cent or more silicon) ...	221,387	11,405,060	233,428	12,119,465
Ferromolybdenum and calcium-molybdenum compounds	210	236,957	1,096	1,051,881
Ferrotungsten	1,238	1,991,123	1,771	2,900,053
Ferrovanadium	1,841	4,843,635	1,777	4,721,903
Other varieties[a]	41,651	6,157,660	35,951	6,492,782
	616,222	53,048,100	689,258	61,368,407

[a]1925: Ferrochromium, ferrophosphorus, ferrotitanium, ferrouranium, ferrozirconium, and zirconium-ferrosilicon; 1926: Ferrochromium, ferrophosphorus, ferrotitanium, ferrozirconium, and zirconium-ferrosilicon.

NO SUBSTITUTES FOR MANGANESE IN STEEL

IN the manufacture of steel, no satisfactory substitute for manganese is known, declares the United States Bureau of Mines. In Germany during the years 1917 and 1918, the shortage of manganese necessitated trial of many substitutes, such as aluminum in the form of silicon-aluminum alloys. Aluminum has a greater affinity for oxygen than manganese, but the oxidization of aluminum produces alumina which is relatively infusible and often remains in the steel as slag inclusions. Aluminum cannot eliminate sulphur or change the condition of sulphur as manganese can. A slight excess of aluminum tends to produce large pipes in the ingots. Silicon in the form of ferrosilicon probably has a greater affinity for oxygen than manganese, but its use is attended by the following disadvantages: In slight excess it causes large pipes to form in ingots; the products of oxidation remain in the steel; it has no effect upon sulphur and no effect on the molecular arrangement of the metal. Ferro titanium is the most powerful deoxidizer known. Titanium does not alloy freely with iron and imparts to steel qualities that are not acceptable to the trade. Calcium, sodium, vanadium and boron alloys have been tried as deoxidizers, but homogeneous steel was not produced when they were used.

DISCUSSION—ALUMINUM BRONZE
(Continued from Page 278)

conditions of thermal treatment. Even then their use may provide only a first approximation as noted in the paper for the coefficient varies to a substantial degree with changes in composition. In his own work, the author has applied them with full appreciation of these limitations.

Mr. Tour's comments are the result of inability to preprint this paper. The coefficients of equivalence refer only to structural composition. Two alloys of different chemical composition but containing equal amounts of the same metallographic constituents as a result of the same thermal and mechanical history, may not, however, have the same mechanical properties. The effects of manganese upon the mechanical properties of aluminum bronze are shown in Figs. 19, 20 and 21 as well as Table IX.

Value
70    $31,711,871

83   354,364
82   2,016,088
28   12,119,465

96   1,051,881
71   2,900,053
77   4,721,903
51   6,492,782

58   61,368,407

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Reviews of Recent Patents

By NELSON LITTELL, Patent Attorney
475 Fifth Ave., New York City—Member of A. S. S. T.

1,633,805, Heat Resisting Alloy, Gerald R. Brophy, of Schenectady, New York, Assignor to General Electric Company, a corporation of New York.

This patent describes a heat resisting alloy capable of withstanding high temperatures in air without oxidation. The object of the invention is to produce an alloy which may be used for castings at a cost not much greater than the cost of cast iron and which will have the oxidation resisting properties of the more expensive nickel and chromium alloys. The new alloy preferably comprises aluminum 10 per cent, chromium 5 per cent, nickel 30 per cent and iron 55 per cent. The nickel reduces the brittleness which would otherwise be imparted by the high aluminum content and the chromium is used to reduce the grain size and otherwise improve the property of the alloy.

1,634,319, Method and Apparatus for Heat Treating Metal Articles, Thomas F. Callaghan, of Bellefonte, Pennsylvania, Assignor to Erwin C. Uihlein, of Milwaukee, Wisconsin.

This patent describes an apparatus for heat treating metallic articles comprising a chamber 1 which is divided into an upper heating furnace 7
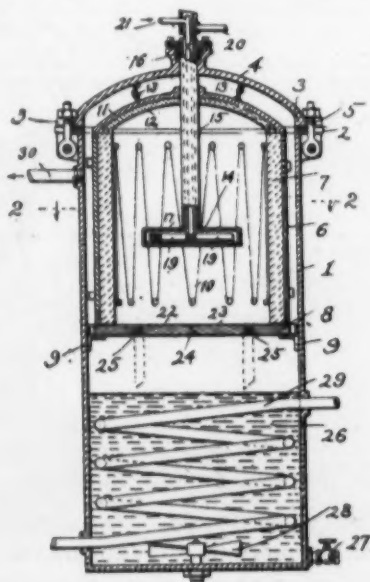
and a lower quenching tank 26. The furnace 7 is heated by means of resistance wires 10 and a pipe 30 is provided, connected to a suitable

source of vacuum, for exhausting the air from the furnace chamber. The articles to be treated are supported in the center of the furnace by the support 14 on the arms 17 which may be water cooled by means of the pipes 19, 20 and 21. The articles are inserted on the support by raising the lid 4 and when received in the furnace are subjected to the heat radiated from the resistance wires 10 and from the walls and the top of the furnace. When the proper temperature has been attained by the articles, the doors 22 and 23 of the quenching compartment are opened and the support 14 with the articles thereon lowered into the quenching fluid. Since both the heating and quenching operations are carried out in partial vacuum, scaling and oxidation, which usually takes place in the hardening operation, is avoided.

1,634,343, Alloy, George O. Smith, of East Orange, New Jersey, Assignor to Western Electric Company, Incorporated, of New York, N. Y., a corporation of New York.

This patent describes an alloy for producing springs adapted to retain their resiliency at high temperature without becoming brittle. The ability to retain resiliency in a spring at high temperature is imparted by the use of a metal of the tungsten group in the percentage of 5 to 40 per cent and the remainder iron. The higher the amount of the tungsten, the greater the tendency to retain resiliency after heating to a red heat, and also the greater tendency toward brittleness. Nickel may be also used in the iron group. Brittleness may be reduced by using a mixture of tungsten, molybdenum and chromium. A series of compositions, suitable for forming the desired alloy, is given as follows:

	Per cent		Per Cent
Cobalt	15	Nickel	60
Chromium	15	Tungsten	40
Tungsten	5		
		Nickel	80
Nickel	54	Chromium	20
Iron	10		
Manganese	1	Nickel	90
		Tungsten	10
Nickel	33.5–34		
Iron	25	Nickel	95
Molybdenum	25	Molybdenum	5
Chromium	15		
Manganese	1–1.5		

1,634,586, Method of Manufacturing Malleable Cast Iron, Masakichi Kubo, of Tokyo, Japan.

This patent describes a method and apparatus for making malleable iron in a more economical manner than the process now used. The method comprises firmly packing the white iron castings 12 in an iron oxide or hematite 13, then heating the same in an electric or other suit-

able furnace, such as 15, to a temperature within the critical range, and then passing an electric current through the electrodes 14 and through the packing 13 and castings 12 while in the heated condition
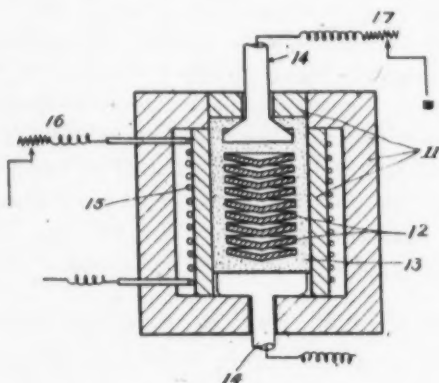
for the purpose of accelerating the change from the white to the malleable iron. An alternating current is preferably used and the process can be completed in a very much shorter time than in the present malleable practice.

1,634,858, **Normalizing Furnace, William J. Stoop, of Wheeling, West Virginia.**

This patent describes a furnace for normalizing metal sheets to remove the strains to which they are subjected during the rolling opera-

tion. The furnace comprises a gas or oil fired chamber heated by means of burners 2 through which the sheets are conducted by means of a series of hollow rolls 1 having the corrugations 1a and 1b staggered so
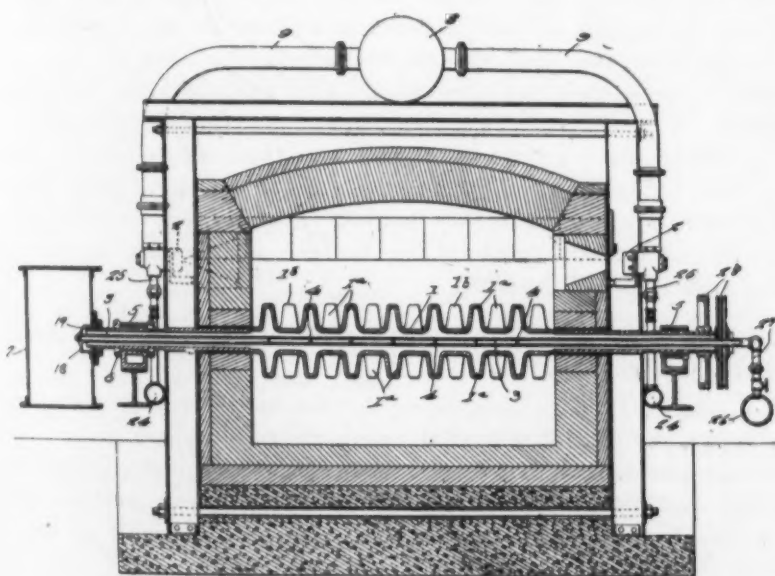
as to convey the sheets substantially without bending the same from end to end of the furnace. The rolls 1 are cooled by blowing air from the manifold 26 to the interior of the rolls permitting escape through the openings 4 in the pipe 3 extending through the rolls. The rolls are rotated by means of the pulleys 23. The air passing through the interior of the rolls becomes highly heated and as it escapes at the end of the furnace opposite the pipes 26, it is conducted to a box-like conduit 7 extending along side of the furnace which in turn is connected at the end of the furnace to the air conduit 8 passing over the top of the furnaces and from the conduit 8 the heated air from the box 7 is conveyed by the branch conduits 9 through the burners 2 located along each side so as to use the preheated air for combustion purposes.

1,635,025, Quenching Fluid, Guy M. Ball, of Dayton, Ohio.

This patent describes a quenching fluid for hardening ferrous metals which tends to cool the quenched articles more uniformly than an ordinary brine or oil quenching baths so as to prevent buckling or warping of the same. The quenching solution is preferably composed of two pounds sodium chloride, one-quarter pound potassium cyanide and one pound borax to one gallon of water.

1,635,384, Case Hardening Process for Steel Articles, Franz Pacher, of Dusseldorf-Rath, Germany.

This patent describes a method of case-hardening a steel article having an inner core of high tensile strength and toughness which comprises first carburizing the desired portion of the article and then heat treating the carburized portion in such a manner as to harden the same without permitting the heat to penetrate into the tougher core a sufficient distance to harden the core also. The heat treating is preferably accomplished by bringing the casehardened portion very quickly to a hardening temperature before the heat has time to penetrate into the core and then quenching. The heating of the casehardened portion is preferably carried out in a highly heated bath of lead or other metallic alloy capable of quickly heating the surface of the article before the heat penetrates into the interior.

1,628,376, Electric Furnace, Irving R. Valentine, Erie, Pa., assignor to General Electric Company.

In this electric furnace comprising a refractory crucible provided with a duct in which the charge is heated by an electric current passed through it, a reservoir provides a hydrostatic head of molten charge communicating with the duct between the ends thereof from which molten charge is supplied to the duct to prevent rupture of the electric circuit by the pinch force acting on the molten charge in the duct.

1,629,508, Blast Furnace, Julian Kennedy, Pittsburgh.

This patent covers laterally adjustable means carried by the hopper for guiding and centering the big bell on a blast furnace.

THE ENGINEERING INDEX

Registered United States, Great Britain and Canada

Arrangements have been made with The American Society of Mechanical Engineers whereby the American Society for Steel Treating will be furnished each month with a specially prepared section of The Engineering Index. It is to include items descriptive of articles appearing in the current issues of the world's engineering and scientific press of particular interest to members of the American Society for Steel Treating. These items will be selected from the copy prepared for the annual volume of the Index published by the A. S. M. E.

In the preparation of the Index by the staff of the A. S. M. E. some 1,200 domestic and foreign technical publications received by the Engineering Societies Library (New York) are regularly searched for articles giving the results of the world's most recent engineering and scientific research, thought, and experience. From this wealth of material the A. S. S. T. will be supplied with a selective index to those articles which deal particularly with steel treating and related subjects.

Photostatic copies (white printing on a black background) of any of the articles listed may be secured through the A. S. S. T. The price of each print, up to 11 by 14 inches in size, is 25 cents. Remittances should accompany orders. A separate print is required for each page of the larger periodicals, but whenever possible two pages will be photographed together on the same print. When ordering prints, identify the article by quoting from the Index item: (1) Title of article; (2) name of periodical in which it appeared; (3) volume, number, and date of publication of periodical; and (4) page numbers.

ALLOY STEELS

ALLOYS, EFFECT OF. Effect of Alloys Upon the Structure and Physical Properties of Steel, H. M. Boylston. Fuels & Furnaces, vol. 5, no. 6, June, 1927, pp. 705-712, 6 figs. Discussion of effect of alloys on critical points and variation in heat treatment due to difference in compositions; suitability of various alloy steels for different applications.

ALLOYS

RECRYSTALLIZATION. Recrystallization of Rare-Metal Alloys (Rekristallisation und Entfestigung von Edelmetallegierungen), L. Sterner-Rainer. Zeit. für Metallkunde, vol. 19, no. 4, Apr. 1927, pp. 149-153, 4 figs. Points out that measurement of grain size and X-ray photographs of cold-worked and annealed metals and alloys have as yet given no complete explanation of recrystallization; changes of certain mechanical properties of rare-metal alloys through heat treatment show that with silver alloys, and in greater degree gold alloys, strain hardening occurs with moderate heating, magnitude of which can be numerically determined; manner of this change is still unknown.

TECHNICAL, FRANCE. The New Alloys —Processes of Deformation (Les nouveaux alliages—les procédés de travail par deformation). Technique Moderne, vol. 19, no. 10, May 15, 1927, pp. 290-292, 4 figs. Alloys employed in France for production of high-speed tools; miramant an equivalent to American alloy, stellite, with melting point above 2500 deg. cent.; alloys cast in chill mold; foundry metals; cold and hot forging; rolling, cutting and stamping.

ALUMINUM

BREWERY INDUSTRY. Aluminum in the Brewery Trade, M. von Schwartz. Eng. Progress, vol. 8, no. 5, May 1927, pp. 129-130, 6 figs. Experience in pre and post-war times has shown aluminum to be eminently suitable for fermenting and storage casks, for yeast cultivators, and numerous smaller implements and utensils in brewery trade; degree of purity of aluminum best suited for such brewing utensils and implements is not definitely determined yet; presumably, aluminum with purity of 99 per cent will be given preference over qualities containing 98 to 99 or 99.5 per cent of pure aluminum.

CASTINGS. How Aluminum Castings Are Made, E. V. Pannell. Am. Metal Market, vol. 34, no. 118, June 18, 1927, pp. 6, 8 and 10-12, 16 figs. Points out that light-alloy melting and molding departments should be kept distinct and entirely different routine established; properties of aluminum-copper-silicon alloys; mixing, melting, molding and pouring; testing; standard aluminum casting alloys.

CEMENTATION. Cementation of Aluminum by Copper (Cementations de l'aluminium par le cuivre), J. Cournot and E. Perot. Académie des Sciences—Comptes Rendus, vol. 183, no. 25, Dec. 20, 1926, pp. 1289-2191. Trying various methods, authors obtain best results by heating aluminum cylinders to be treated in neutral atmosphere in electric furnace after having deposited electrolytic copper on specimen; cementation sets in above 544 deg. cent.; as temperature rose up to 660 deg. penetration of alloy into core increased continuously to 1.59 mm., but Brinell hardness attained its maximum near 615 deg.

CHEMICAL INDUSTRY. Aluminum Ware (Das Aluminium als Werkstoff in der chemischen Industrie), H. Röhrig. Chemiker-Zeitung, vol. 51, no. 25, Mar. 30, 1927, pp. 237-238. Aluminum as material of construction is useful for many chemical processes and products, including nitric acid, explosives, coke by-products, petroleum refining, fats and oils, fermentation industries and dyes; many alloys are in use; in some cases metal is given protective coating.

CRYSTALS, BEHAVIOR UNDER TENSION. Behavior of Aluminum Crystals under Tension (Das Verhalten von Aluminiumkristallen bei Zugversuchen), von Göler and G. Sachs. Zeit. für Physik, vol. 41, nos. 2-3, Feb. 10, 1927, pp. 103-115, 6 figs. Mathematical analysis of simple and double slipping of aluminum crystals when under tension.

MELTING AND CASTING. Characteristic Properties of Aluminum under influence of Melting and Casting (Das Schmelzen und Giessen des Aluminiums), E. Richards, Giesserei-Zeit., vol. 24, no. 6, Mar. 15, 1927, pp. 156-160. Influences of different melting apparatus on quality of product; melting process and deoxidation medium; importance of determination of proper casting temperatures.

ALUMINUM ALLOYS

CORROSION. Corrosion Test of Light Metal (Prüfung von Leichtmetallen auf Korrosion), E. Rackwitz and E. K. O. Schmidt. Korrosion u. Metallschutz, vol. 3, no. 3, Mar. 1927, pp. 58-62, 5 figs. Deals with surface changes, loss of weight, strength and elongation through corrosion.

CORROSION. The Corrosion of Aluminum and Its Alloys in Different Electrolytes (Ein Beitrag zur Kenntnis der Korrosion des Aluminiums und seiner Legierungen in verschiedenen Elektrolyten), N. Isgarischew and W. Jordansky. Korrosion u. Metallschutz, vol. 3, no. 3, Mar. 1927, pp. 54-58, 6 figs. Investigation of corrosion of different aluminum alloys in relation to their copper content in solutions of hydrochloric acid, which are most active and have greatest reproduction capacity of all electrolytes; also investigation of corrosion of pure aluminum in solution of acids.

INCLUSIONS. Inclusions in Light Metals and Their Effect on Their Mechanical Properties (Einschlüsse in Leichtmetallen und ihre Wirkung auf die mechanischen Eigenschaften), H. Steudel. Zeit. für Metallkunde, vol. 19, no. 4, Apr. 1927, pp. 129-137, 30 figs. Given examples showing unfavorable influence of insoluble admixtures in aluminum alloys, through which full utilization of their strength properties is adversely influenced; by referring to metallurgical development of structural steel, methods are indicated for improvement of quality of light alloys.

ALUMINUM BRONZE

PROPERTIES. Aluminum Bronze, J. Strauss. Am. Soc. Steel Treating—Trans., vol. 12, no. 1, July 1927, pp. 68-105, 17 figs. Review of constitution, mechanical properties and resistance to corrosion of these aluminum-copper alloys with and without addition of other elements; survey of portion of non-ferrous field in which mechanical properties, heat-treatment practice and other features are closely allied to those of some ferrous product.

BEARINGS

LEAD BRASS. Bearings Made of Lead Brass. Elec. Ry. Jl., vol. 69, no. 25, June 18, 1927, pp. 1077-1079, 9 figs. Composition used by Market Street Railway is said to have exceptional qualities; reclaimed scrap totals four-fifths of materials used in manufacture.

BLAST FURNACES

AIR HEATERS. Precalculation of Efficiency and Most Favorable Load of Air Heaters (Vorausberechnung der Wirkungsgrades und der günstigen Belastung von Winderhitzern), A. Schack. Stahl u. Eisen, vol. 47, no. 23, June 9, 1927, pp. 965-966, 1 fig. Exhaust-gas loss depends primarily on exhaust-gas temperature; this in turn, is proportional to sum of loads in gas and blast periods, when uniform hot-blast temperature is assumed.

CARBON CONTENT OF PIG. The influence of Blast Furnace Process on Total Carbon Content of Pig Iron (Der Einfluss des Hochofenganges auf den Gesamtkohlenstoffgehalt), A. Michel. Stahl u. Eissen, vol. 47, no. 17, Apr. 28, 1927, pp. 696-698, 3 figs. It is shown that carburization process in blast furnace has no important bearing on final carbon content of pig iron; this is determined by temperature and slag in furnace.

GAS SAMPLING AT VARIOUS ELEVATIONS. Composition of Materials from Various Elevations in the Blast Furnace. Foundry Trade Jl., vol. 35, no. 565, June 16, 1927, pp. 498-500, 1 fig. Investigation by U. S. Bur. of Mines of gas composition, temperature and pressure at series of planes in blast furnace making foundry iron in Southern district.

OXYACETYLENE APPLIED TO. Iron Blast Furnaces. Iron & Steel of Can., vol. 10, no. 5, May 1927, pp. 140-145, 13 figs. It is in maintenance of mechanical equipment that oxyacetylene process finds its most diverse uses; blowing in with oxygen.

BOILERS

DRUM MANUFACTURE. Manufacture of High-Pressure Boiler Drums. Iron Age, vol. 119, no. 18, May 5, 1927, p. 1300. Welding of longitudinal seams 3½ in. thick and upsetting of ends to close in head; methods of Thyssen firm in Germany.

BRASS

ANALYSIS. Rapid Analysis of Brass (Schnellanalyse von Messing), S. von Bogaandy and M. Polanvi. Zeit. für Metallkunde, vol. 19, no. 4, Apr. 1927, pp. 164-165, 2 figs. Determination of zinc and lead in brass; method can be carried out in a few minutes.

SULPHUR IN. Sulphur in Brass. Foundry Trade Jl., vol. 35, no. 564, June 9, 1927, p. 487. Sulphur and rolling troubles; it has been repeatedly demonstrated that of all different impurities present while working brass, sulphur is apparently least likely to cause trouble.

BRONZES

MACHINING. The Machining of Special Bronzes. Metal Industry (N. Y.), vol. 25, no. 6, June 1927, p. 249. Suggestions for working of different alloys.

CAR WHEELS

SOLID ROLLED-STEEL. The Manufacture of Solid Rolled Steel Car Wheels, G. A.

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Richardson. Ry. & Locomotive Eng., vol. 40, no. 5, May 1927, pp. 137-138. Steel is cast into large ingots which are rolled in 32-in. mill to round blooms of diameter to suit best size and type of wheel to be made; blooms are sheared hot with rotary shears into blocks of desired length steps in manufacturing; inspection and machining.

CAST IRON

BLOWHOLES. The Macrostructure and Microstructure of Blowhole Segregations (Die Makro und Mikrostruktur von Gasblasenseigerungen), A. Wimmer. Stahl u. Eisen, vol. 47, no. 19, May 12, 1927, pp. 781-786, 23 figs. partly on supp.-plates. Describes occurence, origin and chemical composition of blowhole segregations, their structure, behavior of carbon, phosphorus, and ferrite with secondary crystallization.

DECARBURIZATION. The Decarburization of Cast Iron (Étude des Phénomènes de Décarburation), M. Leroyer. Fonderie Moderne, vol. 21, June 10, 1927, pp. 149-153, 7 figs. Influence of factors of time, temperature, strength of ore, and thickness of molds on decarburization.

GAS CONTENT OF LIQUID CHARGE. The New Process for Determination of Gas Content of Liquid Metal Charges. (Ein neues Verfahren zur Bestimmung des Gasgehaltes von flüssigen Metallschmelzen), A. Wüster and E. Piwowarsky. Stahl u. Eisen, vol. 47, no. 17, Apr. 28, 1927, pp. 698-702, 5 figs. Review of existing literature; results of investigation on different cast-iron specimens; influence of overheating on quality and composition of gas; practical applicability of process.

GRAPHITE IN. Graphite in Gray Cast Iron (Der Graphit im grauen Gusseisen), P. Bardenheuer. Stahl u. Eisen, vol. 47, no. 21, May 26, 1927, pp. 857-867, 48 figs. partly on supp. plates. Significance of graphite content in cast iron; theory of graphite separation; relation between conditions of crystallization of graphite and its form and distribution; influence of graphitization on properties of gray cast iron; older and new method for removal of graphite.

GRAPHITIZATION. The Influence of Melting Temperature on Graphitization (Ueber den Einfluss der Schmeiztemperatur auf dei Graphitabildung), T. Klingenstein. Giesserei Zeitung, vol. 24, no. 12, June 15, 1927, pp. 335-340, 15 figs. Review of practical and scientific works with view of obtaining carbon-poor cast iron with finely distributed graphite; report on tests of author to determine influence of melting and superheating temperature on graphitization; form of removed graphite with normal cooling and rapid heating to maximum temperature.

GROWTH. Distortion and Growth in Cast Iron on Repeated Heating, J. G. Hurst. Chem. Age, vol. 16, no. 414, June 4, 1927, pp. 41-42 (Met. Sect.). Growth of cast iron under repeated conditions of heating and cooling is discussed, and compared with "spalling" phenomenon exhibited by refractory materials.

GROWTH. The Growth of Cast Iron (Das Wachsen des Gusseisens), K. Sipp and F. Roll. Giesserei-Zeit., vol. 24, nos. 9 and 10, Mar. 1 and 15, 1927, pp. 229-244 and 280-284, 32 figs. Review of existing

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literature; tests to determine behavior of cast iron with superheated steam of 450 to 500 deg., with annealing of temperature at 600 to 1000 deg. and when stressed to melting point.

HEAT TREATMENT, EFFECT OF. Effect of Heat Treatment on the Combined Carbon in Gray Cast Iron, E. L. Roth. Am. Soc. Steel Treating—Trans., vol. 12, no. 1, July 1927, pp. 27-40, 13 figs. Results of series of experiments; heat treating is necessary when sufficient carbon has combined to form hard spots of cementite; microscopic examination shows that formation of graphitic carbon is propagated from edges toward center; it is believed that silicon does not have marked effect on graphitization; it is also shown that degree of graphitization does not increase with rising temperature.

MECHANICAL CLEANING. Means for Prevention of Defective and Production of Good Castings (Einiges über Mittel zur Vermeidung fehlerhafter sowie zur Erzielung guter Gussstücke), F. Brandenburg. Giesserei, vol. 14, no. 22, May 28, 1927, pp. 353-354, 4 figs. Describes two arrangements for mechanical cleaning of cast iron, which do not take place of deoxidation in ladle by aluminum but supplement this procedure.

MOLTEN, TEMPERATURE MEASUREMENT. Temperature Measurement of Molten Cast Iron, Basic Pig Iron and Steel (Temperaturmessungen von flüssigem Gusseisen, Thomasroheisen und Stahl), M. Wenzl and F. Morawe. Stahl u. Eisen, vol. 47, no. 21, May 26, 1927, pp. 867-871, 4 figs. Measurements in iron foundry, including measurement of iron bath in reverberatory furnaces with thermo-couples; measurement of iron flow in reverberatory furnaces and cupolas by optical means and with thermocouples; temperature measurement of iron in ladle; measurement of basic and openhearth steel.

NICKEL IN. Nickel Changes Properties of Gray Cast Iron, D. M. Houston. Foundry, vol. 55, nos. 10 and 11, May 15 and June 1, 1927, pp. 399-401 and 423-425, 7 figs.; Also in Am. Mach., vol. 66, no. 23, June 9, 1927, pp. 961-962, 3 figs. Explains effect and use of nickel; points out stabilizing effect of nickel on combined carbon related to casting conditions; from 0.5 to 0.75 per cent nickel has been found to overcome both variations of cupola and casting conditions, economic phases of nickel addition; it makes pre-annealing unnecessary.

OVERHEATING. Theoretical Principles of Overheating Gray Cast Iron (Theoretische Grundlagen der Graugussüberhitzung), H. Hanemann. Stahl u. Eisen, vol. 47, no. 17, Apr. 28, 1927, pp. 693-695, 3 figs. Derivations from diagram of state of iron-carbon alloys; stable saturation curve for bound carbon; conditions under which saturation curve is reached, exceeded, and not reached; discusses overheating theory of E. Piwowarsky.

SHRINKAGE. Some Aspects of Foundry Work, E. Longden. Foundry Trade Jl., vol. 35, nos. 563 and 564, June 2 and 9, 1927, pp. 463-465 and 475-480, 32 figs. Author's opinion is that liquid shrinkage in gray iron as is generally made evident by cavity and porosity is caused, mainly, by mold and

occluded gases, but that there is also abundant evidence to prove that degree of resistance offered by mold material to gray iron when cooling has important bearing on solidity of metal; it would appear that actual metal shrinkage, except in very strong iron, is practically nil; mold materials and density of castings; spherical castings; cause of mold disturbances; porosity of molding sand; running arrangements. June 9: construction of mold; two grades of metal in same casting; making lathe bedplate; molding hydraulic cylinders, rams and heavy flywheels with special reference to moldingbox construction; heavy flywheels; semi-permanent or long-life molds.

VOLUME CHANGE DURING SOLIDIFICATION. On the Volume Change in Cast Iron during Solidification, with a Criticism of the Double Diagram of the Iron-Carbon System. K. Honda and H. Endo. Tôhoku Imperial Univ.—Sci. Reports, vol. 16, no. 1, Feb. 1927, pp. 9-25, 8 figs. Measurement carried out, by means of thermobalance, with object of confirming view that in iron-carbon system, graphite formed during solidification.

CASTING

CENTRIFUGAL. Centrifugal Tube Casting in Hot Molds, L. Cammen. Foundry Trade Jl., vol. 35, no. 565, June 16, 1927, pp. 501-502. Abstract of paper read before American Foundrymen's Association in 1926. Materials for heated molds; experiment to develop mold material; protecting mold surface from solvent action of hot steel; temperature of hot molds.

CHROMIUM STEEL

CHROMIUM-COBALT. Chromium and Cobalt Steels (Note sur les aciers au chrome et au cobalt), F. M. Ostroga. Revue de Métallurgie, vol. 24, no. 3, Mar. 1927, pp. 135-145, 22 figs. Two steels used for exhaust valves for internal-combustion engines have been studied by dilatometric and microscopic methods and their Brinell hardness determined; steels are not readily oxidizable at high temperatures, transformation temperature on heating is 850 deg. and hardness is 60 at 800 deg.; in malleable condition they are easily machinable.

CORROSION. Methods to Investigate Rapidity of and Susceptibility to Corrosion of High-Grade Steel, with Special Reference to Origin of Corrosion in Stainless Steel (Untersuchungsmethoden über die Rostgeschwindigkeit und-neigung von Qualitätsstählen mit besonderer Berücksüchtigung der Korrosionsquellen an rostsicheren Chromstählen). V. Duffek, Korrosion u. Metallschutz, vol. 3, no. 3, Mar. 1927, pp. 49-53, 4 figs. Author seeks to demonstrate adaptability of certain investigating methods.

COAL GAS

WELDING AND CUTTING, APPLICATION TO. Heating and Illuminating Gas in Welding and Cutting Metals, S. Cockerill. Gas Age-Rec., vol. 59, no. 24, June 11, 1927, pp. 855-856. While primary object of using coal gas or water gas mixed with other gases in welding and cutting is to lower cost, yet there are stated to be other reasons such as increased calorific value of

these mixtures over calorific value of hydrogen alone.

COKE

COMBUSTIBILITY. The Combustibility of Coke, W. Diamond. Foundry Trade Jl., vol. 35, no. 562, May 26, 1927, pp. 448-450. Recovery coke ovens; structural strength of coke; cupola; volume and pressure of blast.

COPPER

ANNEALING. The Annealing of Copper, N. R. Stansel. Fuels & Furnaces, vol. 5, no. 5, May 1927, pp. 615-618, 4 figs. Determination of recrystallization temperature of cold-worked metals; effect of annealing on properties of copper; use of electric furnace for annealing operation.

CAST. The Significance of Structure of Cast Copper for Analyzing Properties of Copper (Die Bedeutung des Gussgefüges für die Eigenschaften von Kupfer), O. Bauer and G. Sachs. Metall u. Erz, vol. 24, no. 7, Apr. 1, 1927, pp. 154-164, 43 figs. Gives examples of defects in copper; indication of density through determination of specific gravity and by means of X-ray investigation; defects due to blowholes; embrittlement.

CAST. The Structure and Surface Formation of Cast Copper (Ueber Gefügeaufbau und Oberflachenbildung bei gegossenem Kupfer), P. Siebe and L. Katterbach. Zeit. für Metallkunde, vol. 19, no. 5, May 1927, pp. 177-186, 21 figs. Influence of ingot temperature, casting temperature and speed of casting on structure of cast copper.

CRYSTALLITE ORIENTATION. Crystallite Orientation of Copper in Relation to Degree of Rolling (Ueber die Kristallitenorientierung in Abhängigkeit vom Walzgrade beim Kupfer) G. Tammann and H. H. Meyer. Zeit. für Metallkunde, vol. 19, no. 3, Mar. 1927, pp. 82-84, 2 figs. On rolling copper crystallites slip along an octahedral plane and, until reduction of 30 to 40 per cent in thickness has been effected, proportion of octahedral planes in plane of rolling increases; further work results in breaking up of elongated crystals in direction perpendicular to direction of rolling, and finally these lamellae split up into long, narrow fibers which are apparently twinned; up to about 40 per cent reduction proportion of octahedral planes on surface increases, but with 50 per cent reduction they have practically disappeared, giving place to dodecahedral planes; after annealing at 400 to 500 deg., surface crystallites are practically all so oriented that an octahedral plane lies with its apex in direction of rolling; severely cold-rolled sheets, however, pass through transition state in which there is large proportion of unevenly oriented dodecahedral planes in surface.

COPPER ALLOYS

MELTING. The Melting of Alloys (Etat actuel du problème de la fusion des alliages), M. Fourment. Revue de Métallurgie, vol. 24, no. 4, Apr. 1927, pp. 179-193, 26 figs. Deals especially with alloys having copper as their base such as brasses and bronzes and also with aluminum alloys; types of melting furnaces; electric melting furnaces of arc and induction type.

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CORROSION

CAUSES AND PREVENTION. Corrosion,
Its Causes and Prevention, C. E. Texter.
Power, vol. 66, no. 1, July 5, 1927, pp. 33-
34. Theory of corrosion; factors that are
becoming more severe; boiler-water treat-
ment. Abstract from paper presented at
Nat. Board of Boiler and Pressure Vessel
Inspectors.

CORROSIVE WATERS. Corroding Effect
of Certain Waters on Metals and Mortars
(Metalle und Mörtel angreifende Wässer), H.
Klut. Korrosion u. Metallschutz, vol. 3, no.
5, May 1927, pp. 101-103. Discusses waters
which have corrosive effect on metals and
concrete mortars; for boiler-feed purposes,
especially in case of soft waters, a higher
silicic-acid content is injurious; waters with
high content of gypsum and magnesium
chloride are unsuitable for boiler feed; for
concrete construction, waters with high con-
tent of sulphate and magnesium salts are in-
jurious. Bibliography.

CRYSTALS

FLOW IN. The Danger of Flow in Metal
Crystals (Zur Fliessgefahr von Metallkristal-
len), E. Schmid. Zeit. für Metallkunde, vol.
19, no. 4, Apr. 1927, pp. 154-157, 7 figs.
With aid of models, flow danger of hexagonal
zinc crystals and regular surface-centered
crystals is shown.

GROWTH. An Investigation of the Rate
of Growth of Crystals in Different Directions,
M. Bentivoglio. Roy. Soc.—Proc., vol. 115,
no. A770, June 1, 1927, pp. 59-87, 21 figs.
Extension of Wulff's experimental work to
other double sulphates; experiments have
also been made to determine whether initial
habit has any influence on rate of growth
of various faces; deals with question whether
polar crystal may grow at different rates
at its two ends.

CUPOLAS

FLUORSPAR IN. · More About Fluorspar
in the Cupola. Iron Age, vol. 119, no. 23,
June 9, 1927, p. 1662. Prominent German,
B. Osann, makes rejoinder and advocates its
use; sulphur reduced by thin slag, manga-
nese and jolting. Prepared from German and
commented on by R. Moldenke.

FLUORSPAR IN. The Effect of Fluorspar
as Cupola Addition in the Iron Foundry (Die
Wirkungsweise des Flusspats als Kuppelofen-
Zuschlag in der Eisengiesserei), Osann. Stahl
u. Eisen, vol. 47, no. 21, May 26, 1927, pp.
881-884. Critical discussion of article in
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E. Wilke-Dörfurt and H. Buchholz, depre-
cating use of fluorspar in cupola opera-
tion; present author advocates its use and
states his reasons; includes reply by E.
Wilke-Dörfurt.

FLUORSPAR IN. The Role of Fluorspar
in the Cupola. Foundry Trade Jl., vol. 35,
no. 565, June 16, 1927, pp. 508-510, 4 figs.
Experiments show that fluorspar flux has no
desulphurizing effect upon molten iron; more-
over, it is to be rejected from metallurgical
point of view, as it increases loss of iron,
manganese and silicon, because of increased
amount of slag. Translated from Stahl u.
Eisen.

GAS ANALYSIS. Automatic Gas Analysis

in Cupola Practice (Erfahrungen mit der
automatischen Gasanalyse im Kupolofenbe-
trieb), H. Pinsl. Giesserei, vol. 14, no. 23,
June 4, 1927, pp. 374-384, 14 figs. Appara-
tus employed and comparison of their merits.

MELTING PROCESS. Cupola Melting and
High-Grade Cast Iron (Kupolofenschmelzen
und veredelter Guss), C. Rein. Giesserei-
Zeit., vol. 24, no. 7, Apr. 1, 1927, pp. 173-
179, 10 figs. Critical discussion of article
by W. Hollingerbäumer published in Gies-
serei, on cupolas; basic condition for cupola
melting process; desulphurizing of cast iron
and equipment developed for this purpose;
slag collector; Dürkopp-Luyken-Rein process;
refining of cast iron.

OPERATION. Comparative Study of the
Operation of Cupolas (Etude comparative du
Fonctionnement d e s Cubilots), Poumay.
F o n d e r i e Moderne, vol. 21, May 25,
1927, pp. 136-140. Establishment of heat
balances and their signification; factors de-
termining economy of cupolas; determina-
tion of calorific power required to cast 100
kg. of pig iron.

POUMAY SYSTEM. Important Develop-
ment in Cupola Practice. Foundry Trade Jl.,
vol. 35, no. 563, May 26, 1927, pp. 433-434,
2 figs. Details of Poumay system of cupola
practice at works of Kryn & Lahy Metal
Works; this is first installation of its kind in
Great Britain, and management are more
than satisfied with results of preliminary
trials and intend converting their second
cupola at earliest opportunity.

TESTING CAST IRON. The Small Cupola
for Testing of Castings (Le petit cubilot
moderne pour les essais de fontes), A. Defer.
Fonderie Moderne, vol. 21, Mar. 25, 1927,
pp. 28-29, 1 fig. This small model has same
general characteristics as large cupolas, action
of melting occurring under same physical and
mechanical condition; it has melting capac-
ity of 400 to 500 kg. per hour; it may also
be employed ·in bronze and aluminum foun-
dries.

DIE CASTING

ALUMINUM. Notes on Aluminum Die-
Casting, F. A. Livermore. Metal Industry
(Lond.), vol. 30, no. 23, June 10, 1927, pp.
571-572. Die-casting machines; dies, alloys;
method of die casting.

DURALUMIN

ANODIC OXIDATION. The Anodic Oxi-
dation Treatment of Duralumin, W. Nelson.
Aviation, vol. 22, no. 24, June 13, 1927, pp.
1288-1289 and 1315, 4 figs. Treatment con-
sists of oxidizing surface of part by mak-
ing it anode in chromic-acid solution through
which electric current is direct; it renders
aluminum very resistant to corrosive influ-
ences; but full benefit of this type of oxi-
dized surface is not obtained without use of
final paint or varnish finish; disadvantage in
treating individual pieces; treatment carried
out in steel tank.

CORROSION. Effect of Corrosion upon the
Fatigue Resistance of Thin Duralumin, R. R.
Moore. Am. Soc. Testing Matls.—Advance
paper, no. 37, for mtg. June 20-24, 1927,
7 pp., 5 figs. Results of fatigue tests on
thin-gage corroded duralumin to determine
effect of embrittlement of duralumin, due to

corrosion, in terms of resistance of metal to repeated stresses or fatigue; results show effect of certain degree of corrosion upon endurance limit; corrosion of duralumin occurs predominantly along grain boundaries ("intercrystallin") and is of continuous or progressive nature rather than local pitting type, although some of latter is present; method of making accurate fatigue tests on thin-gage light metals.

SPOT-WELDED. Tension Tests of Spot-Welded Duralumin, T. W. Downes. Chem. & Met. Eng., vol. 34, no. 6, June 1927, pp. 359-360, 4 figs. Deals principally with tension and corrosion tests of electric spot-welded specimens of sheet duralumin which have been conducted at Naval Aircraft Factory; heat treatment of specimens; character of welds.

EDUCATION, ENGINEERING

FOUNDRY INSTRUCTION. Professional and Technical Training in the Foundry Trade (L'Enseignement Professionnel et Technique de l'Industrie de la Fonderie), A. Soupart. Fonderie Moderne, vol. 21, May 10, 1927, pp. 115-119, 1 fig. Studies means of promoting and assuring success of training.

ELECTRIC FURNACES

ARC. Arc Furnace Design Involves Numerous Features, W. E. Lewis. Foundry, vol. 55, no. 11, June 1, 1927, pp. 436-439, 6 figs. In design of electric furnaces best results can be obtained only by properly correlating voltage, wattage, electrode spacing, furnace dimensions, etc.; regulation of power.

BASIC. Reaction Phenomena in Basic Electric Furnaces (Reaktionsvorgänge im basischen Elektroofen), K. v. Kerpely. Giesserei-Zeit., vol. 24, no. 4, Feb. 15, 1927, pp. 98-101. Oxidation and deoxidation; influence of slagging and composition on quality of steel and of cast iron; present status of triple slagging. See also discussion in no. 8, Apr. 15, 1927, pp. 207-208.

DEVELOPMENTS. Developments in Electric Heat, G. H. Schaeffer. Iron & Steel Engr., vol. 4, no. 6, June 1927, pp. 276-281. Report covering field of electric heat for period that has elapsed since 1926 convention at Chicago; deals with electric melting; high-temperature and low-temperature furnaces; roll heaters; hardening high-speed steel; heat treatment of rails; combined use of electricity with other fuel; bright annealing; electric heating of hot tops of steel ingots; high-frequency furnace developments.

FOUNDRIES. Alloys Iron Electrically, F. G. Steinebach. Foundry, vol. 55, no. 11, June 1, 1927, pp. 433-435 and 439, 3 figs. Pennsylvania foundry makes ingot molds from cupola iron and wear-resisting castings from electric-furnace metal.

FOUNDRIES. The Economy of Electric Furnaces in Foundries (Die Wirtschaftlichkeit des Elektroofens in der Giesserei), E. Kothny. Giesserei-Zeit., vol. 24, no. 3, Feb. 1, 1929, pp. 57-68 and (discussion) no. 7, Apr. 1, 1927, pp. 185-188, 12 figs. Unit system for calculation of initial costs of material to be melted; comparative costs for production of standard cast iron in cupolas and electric furnaces; production of synthet-

ic castings; compares production of malleable castings in cupola, open-hearth and electric furnaces; steel and non-ferrous castings.

FOUNDRIES. The Status of Electric Furnaces in Foundries (La situation actuelle du four électrique en fonderie). Jl. du Four Electrique, vol. 36, no. 9, June 15, 1927, pp. 129-132, 2 figs. Deals with furnaces for steel, cast-iron, and non-ferrous-metal foundries.

HEAT-TREATING. Electric Roller Hearth Furnace, O. C. Trautman. Forging-Stamping-Heat Treating, vol. 13, no. 4, Apr. 1927, pp. 142-143, 3 figs. Automobile valve and other springs, are heat treated in trays which, after passing through furnace, discharge into quenching tank and return for loading.

INDUCTION. The Induction Furnace with Filled Ducts (Der Induktionsofen mit erfüllten Kanälen), E. F. Russ. Giesserei-Zeit., vol. 24, no. 9, May 1, 1927, pp. 245-248, 22 figs. Development of induction furnace with filled melting grooves, showing at same time movement of bath in narrow channels.

INDUSTRIAL. Industrial Electric Furnaces in the First Quarter of the Century (Il forno elettrico industriale nel primo quarto del secolo), S. Pagliani. Elettricista, vol. 36, no. 6, June, 1927, pp. 81-87, 8 figs. Deals with furnaces for electrometallurgy; arc furnaces of Stassano and Heroult types.

IRONLESS INDUCTION. The Ironless Induction Furnace (Der eisenlose Induktionsofen), W. Fischer. Giesserei-Zeit., vol. 24, no. 5, Mar. 1, 1927, pp. 117-124, 12 figs. Points out differences between high-frequency and low-frequency induction furnace; electric theory of high-frequency furnace; efficiency and possibilities of application; types and prospects. See also discussion in no. 8, Apr. 15, 1927, pp. 209-210.

MELTING, COST OF POWER. Determination of Electric-Power Cost with Special Regard to Electric Melting (Kostenermittlung für die elektrische Energie unter besonderer Berücksichtigung des elektrischen Schmelzens), F. Knoops. Centralblatt der Hütten u. Walzwerke, vol. 31, no. 18, May 4, 1927, pp. 225-230, 3 figs. Fundamentals for determinations of cost; presents examples showing to what extent cost per kw. hr. are dependent on duration of heating time.

STEEL-MELTING. The New Steel-Melting Arc Furnace (Beschreibung einer neuzeitlichen Lichtbogen-Elektrostahlofenanlage), S. Schey. Centralblatt der Hütten u. Walzwerke, vol. 31, no. 18, May 4, 1927, pp. 231-236, 11 figs. Details of new furnace installed in plant of Schäffer & Budenberg, Magdeburg; mechanical power is supplied by Demag, Duisburg, and electrical equipment by German General Electric Co.; it is used for production of high-grade steel castings from scrap metal.

ELECTRIC WELDING

BOILER REINFORCING STRAPS. Electrically Welded Reinforcing Straps in Boilers and Containers, E. Horn. Mech. Eng., vol. 49, no. 7, July, 1927, pp. 731-734, 11 figs. Particulars regarding early investigations conducted in Switzerland; contributed by author as supplement to his article on auto-

geneously and electrically welded boilers and containers, published in the June 1926, issue of this journal.

BRIDGE STRENGTHENING. Use Electric Welding Process to Strengthen Bridge. Ry. Age, vol. 82, no. 29, June 18, 1927, pp. 1944-1946, 1 fig. Chicago Great Western avoids drilling and riveting in increasing capacity of Leavenworth bridge; new cover plates welded in place.

CAST-IRON MACHINE PARTS. The Electric Cold Welding of Cast-Iron Machine Parts (Die elektrische Kaltschweissung von gusseisernen Maschinenteilen), H. Kochendörffer. Stahl u. Eisen, vol. 47, no. 17, Apr. 28, 1927, pp. 703-705, 6 figs. Special references to application of wrought-iron armatures in welding of heavy machine parts.

ELECTRIC WELDING, ARC

BOILER PLATE. Arc Welding of Boiler Plates, N. Shaposhikoff, G. Kastzenko and K. Jourieff. Inst. Economic Mineralogy & Met.—Trans., no. 31, 1927, 76 pp., 25 figs. Strength tests, chemical analysis, and metallographic studies of V and double-V welds, made at Mining and Metallurgical Laboratory of Leningrad; joining plates, new with new and old with old; results of strength and bending tests very satisfactory; favors V joint for thinner plates, double V for thicker; commends annealing but objects to hammering of welds. (In Russian.)

BUILDINGS. Construction Procedure on Two Arc-Welded Buildings, A. G. Bissell. Eng. News-Rec., vol. 98, no. 23, June 9, 1927, pp. 942-943, 4 figs. All fabrication done in field with connections originally designed for arc welding; saving over like riveted design.

BUILDINGS. Testing the Design Features of an Arc Welded Building, A. M. Candy. Elec. Jl., vol. 24, no. 6, June 1927, pp. 276-283, 26 figs. Tests fully demonstrate that arc-welded joints can be constructed in such manner as to develop fully ultimate strength of structural members connected; beams and girders can be connected to columns so as to produce absolute fixation, etc.

GEARS. Making Gears by Arc Welding. Welding Engr., vol. 12, no. 6, June 1927, pp. 39-42, 6 figs. Radical change in appearance is only an incident in change from cast gear blanks to gear blanks made of welded steel; more important features of two types of gears are compared.

PIPES. Electric Welding of Pipes, J. F. Lincoln. Am. Inst. Elec. Engrs.—Jl., vol. 46, no. 6, June 1927, pp. 593-596 and (discussion) 628-630. Advantages of arc welding in manufacturing instead of riveting or using cast iron; these advantages for manufacturing pipe are especially emphasized and information is given on manufacture of pipe for one particular pipe line, 90 mi. long, for which automatic arc welding is used; possibilities of arc welding pipe joints in field.

STEEL BUILDINGS. Arc-Welded Steel Buildings, G. D. Fish. West. Soc. Engrs.—Jl., vol. 32, no. 4, Apr.-May, 1927, pp. 142-151 and (discussion) 151-160, 20 figs. It promises savings of about one-eighth of steel in buildings by designing for continuity of beams and girders, and prospect of erection without noise and vibration.

STEEL STRUCTURES. Designing Steel Structures for Arc-Welded Connections, A. M. Candy. Engr. Soc. West Pa.—Proc., vol. 43, no. 1, Feb. 1927, pp. 103-114 and (discussion) 115-117. Results of tests to show decided advantages which are made available through use of arc-welded instead of riveted connections.

TANK CONSTRUCTION. Arc Welding Speeds in Tank Construction, R. E. Kinkead. Boiler Maker, vol. 28, no. 6, June 1927, pp. 177, 3 figs. Use of proper electrodes at higher heats for any given work accomplishes gain in speed of manual operation.

THREE-PHASE VS. TWO-PHASE CURRENT. Two-Phase or Three-Phase Current for Electric Arc Welding? (Zwei- oder dreiphasenstrom für die elektrische bogenschweissung?), M. Zack. Autogene Metallbearbeitung, vol. 20, no. 5, Mar. 1, 1927, pp. 73-75, 4 figs. Points out manifold advantages of three-phase rotary current enabling simultaneous welding with two electrodes one of which may be metal and other carbon, etc.; commends use of three-phase rotary arc-welding transformer where only two-phase rotary current is available.

ELECTRICAL MACHINERY

WELDED STEEL CONSTRUCTION. Building Electrical Machinery Without Castings, G. S. Brady. Am. Mach., vol. 66, no. 26, June 30, 1927, pp. 1079-1082, 8 figs. General Electric Co.'s recently adopted policy of substituting welded steel construction for iron and steel castings in building of all of its large electrical machine units. See also description in Iron Age, vol. 119, no. 26, June 30, 1927, pp. 1181-1184.

FOUNDING

HEROIC STATUARY. Making Heroic Statuary, P. Dwyer. Foundry, vol. 55, no. 11, June 1, 1927, pp. 418-422 and 432, 7 figs. Points out that technique employed in molding and casting statuary and other objects of art either in base or precious metal has changed but little since biblical times with single exception that one man's work is divided among many; practice of bronze founding of Gorham Co., Providence, R. I.

FOUNDRIES

DIRECT METAL PROCESS IN. Using Direct Metal in Foundry. Iron Age, vol. 119, no. 26, June 30, 1927, pp. 1869-1872. Blast-furnace iron and cupola iron mixed in Ford plant to obtain desired analysis; electric furnace controls temperature.

FURNACES, ANNEALING

CONTINUOUS. Continuous Furnace Used to Anneal Steel Castings. Iron Age, vol 119, no. 26, June 30, 1927, p. 1897. Annealing period reduced as much as 2 hours by rotary-type oven at Detroit plant.

FURNACES, GAS

INDUSTRIAL. Luminous and Non-Luminous Flame in Industrial Gas Furnace (Leuchtende und nichtleuchtende Flamme in industriellen Gasfeuerungen), K. Huffelmann. Feuerungstechnik, vol. 15, nos. 13, 14, 15

and 16, Apr. 1, 15, May 1 and 15, 1927, pp. 145-146, 160-163, 174-176 and 186-187, 7 figs. Soot removal in flame as result of combustion; heat radiation of flame as result of radiation of gas molecules and solid carbon; calculation of flame radiation based on practical example.

PULVERIZED-COAL-FIRED. Operating Experiences with Pulverized Coal Rolling-Mill Furnaces (Betriebserfahrungen mit kohlenstaubgefeuerten Walzwerksöfen), A. Koegel. Stahl u. Eisen, vol. 47, no. 22, June 2, 1927, pp. 915-918 and (discussion) 918-920, 12 figs. Reasons for installation of pulverized-coal furnaces in Klöckner steel works; operating results.

FURNACES, HEATING

PULVERIZED-COAL-FIRED. Status of Pulverized-Coal Firing in Rolling Mills (Uebersicht ueber den Stand der Kohlenstaubfeuerung in Walzwerken), G. Bulle. Stahl u. Eisen, vol. 47, no. 20, May 19, 1927, pp. 817-826, 15 figs. Advantages and disadvantages; types of pulverized-coal furnaces, including ingot heating and annealing furnaces.

HARDNESS

MEASUREMENT. T h e Microcharacter Measures Hardness, W. W. Boone and Z. G. Deutsch. Metal Industry (N. Y.), vol. 25, no. 6, June 1927, p. 248, 4 figs. Recently developed method of testing for scratch hardness; microcharacter moves sapphire point under fixed pressure of three grams, over highly polished surface of material to be tested.

TESTING. Determination of the Fatigue Hardness of Metals. Eng. Progress, vol. 8, no. 5, May 1927, pp. 131-132, 4 figs. Oscillatory testing machine manufactured by firm of Carl Schenck in Darmstadt permits of testing bar-shaped test pieces under tension and compression alternating at 500 oscillations per second.

HEAT TREATMENT

PRACTICE. Metals and Their Heat Treatment, S. G. Williams. Roy. Aeronautical Soc.—Jl., vol. 31, no. 198, June 1927, pp. 602-613. Deals with heat treatment of alloy steels and light alloys; points out that all functions of hardening and tempering can be better carried out if ideal temperatures are worked to; quenching oil is often not cold enough towards end of day.

HOUSES

STEEL. Standard Structural Sections Form Residence Framework, R. T. Mason. Iron Trade Rev., vol. 80, nos. 20, 21, 22 and 23, May 19, May 26, June 2 and 9, 1927, pp. 1277 and 1283, 1335 and 1343, 1401 and 1441 and 1466; 5 figs. May 19: Progress made in building steel frame house. May 26: Gypsum board replaces wood sheathing. June 2: Speed and simplicity in steel-house erection. June 9: Discussion of costs and possibilities.

STEEL. Steel Frame Adapted to Large Dwelling. Iron Age, vol. 120, no. 1, July 7, 1927, p. 9. Nine-room steel frame dwelling being built in Pittsburgh; walls consist of 6-in. junior beam studs covered on

outside by 1½-in. cork board insulation and 4-in. brick veneer securely fastened to studs by wire ties.

IRON

DESULPHURIZING. The Effect of Alkalies on Iron Baths (Ueber die Einwirkung von Alkalien auf Eisenbäder), P. Bardenheuer and H. Ostermann. Mitteilungen aus dem Kaiser-Wilhelm-Institut für Eisenforschung zu Düsseldorf, vol. 9, no. 6, 1927, pp. 129-149, 2 figs. Theoretical study of reaction process; influence of soda addition on charges of different composition in carbon crucible; desulphurizing with mixtures of soda and siliceous materials and of soda and calcium carbide; tests with alkali metal; relation between desulphurization and slags; effect of lime-soda mixtures; influence of temperature and additions on desulphurization; advantages and disadvantages of alkaline desulphurization. See also abstract in Giesserei, vol. 14, no. 19, May 7, 1927, pp. 305-307.

LOW-TEMPERATURE PRODUCTION. New Iron Progress. Times Trade & Eng. Suppl., vol. 20, no. 465, June 4, 1927, p. 277. Low-temperature process for production of pure iron in granular form from ore at one operation; main stages of process devised by Thomas Rowlands are distillation of coal, preliminary reduction of iron ore, complete reduction of iron ore, magnetic separation of pure metallic iron, revival of spent gases.

PHASE TRANSFORMATION. Thermodynamics of Transformation in Iron (Zur Thermodynamik der Umwandlungen des Eisens), F. Wever. Mitteilungen aus dem Kaiser-Wilhelm-Institut für Eisenforschung zu Düsseldorf, vol. 9, no. 7, 1927, pp. 151-155, 12 figs. partly on supp. plates. Definition of phase and polymorphur transformation as special case of phase transformation; critical study of phase transformation in iron.

SILICON IN. The Quantative Determination of Silicon in Iron (Beitrag zur quantitativen Bestimmung des Siliziums im Eisen) P. Barkenheuer and H. Ploum. Mitteilungen aus dem Kaiser-Wilhelm-Institut für Eisenforschung zu Düsseldorf, vol. 9, no. 11 1927, pp. 207-209, 2 figs. By solution of iron in acid not all of silicon remains as SiO_2 but part of it remains in another combination and develops hydrogen with alkalies; quantity of this compound depends on concentration and amount of dissolving acid; presence of compound makes necessary careful annealing of residue under admission of air.

IRON ALLOYS

BRINELL BALLS, FOR. Iron-Carbon-Vanadium Alloy for Brinell Balls, G. W. Quick and L. Jordan. Am. Soc. Steel Treating—Trans., vol. 12, no. 1, July 1927, pp. 3-24 and (discussion) 24-26 and 50, 5 figs. Special alloy of about 2.9 per cent and 13 per cent vanadium has been experimentally used for Brinell balls in testing of steels of such hardnesses as cause ordinary Brinell balls to deform both elastically and plastically; these special balls, heat-treated, work-hardened, and tested against steels of approximately 700 Brinell, flattened about one-half as much as Hultgren balls and one-fifth as much as ordinary Brinell balls;

board insulation and
ly fastened to studs

The Effect of Al-
Ueber die Einwirk-
isenbäder), P. Bard-
mann. Mitteilungen
-Institut für Eisen-
vol. 9, no. 6, 1927.
Theoretical study of
ce of soda addition
composition in car-
izing with mixtures
aterials and of soda
tests with alkali
desulphurization and
da mixtures; influ-
additions on desul-
and disadvantages
tion. See also ab-
14, no. 19, May 7,

PRODUCTION. New
rade & Eng. Suppl.,
1927, p. 277. Low-
production of pure
rom ore at one op-
process devised by
distillation of coal,
iron ore, complete
magnetic separation
vival of spent gases.

ATION. Thermody-
in Iron (Zur Ther-
ilungen des Eisens),
aus dem Kaiser-
Eisenforschung zu
1927, pp. 151-155,
plates. Definition
r transformation as
ransformation; crit-
asformation in iron.

Quantative Determi-
(Beitrag zur quanti-
Siliziums im Eisen)
Ploum. Mitteilun-
Vilhelm-Institut für
dorf, vol. 9, no. 11
gs. By solution of
silicon remains as
ains in another com-
ydrogen with alka-
ompound depends on
of dissolving acid;
akes necessary care-
under admission of

FOR. Iron-Carbon-
inell Balls, G. W.
m. Soc. Steel Treat-
1, July 1927, pp.
-26 and 50, 5 figs.
.9 per cent and 13
been experimentally
n testing of steels
use ordinary Brinell
lastically and plas-
balls, heat-treated.
d against steels of
ell, flattened about
tgren balls and one-
ary Brinell balls;

opinion that hardness obtainable in plain
carbon steel by combined heat treatment and
coldwork is maximum hardness to be secured
by such treatment, irrespective of composi-
tion of steel, is shown to be untrue; dif-
ference in flattening between iron-carbon-
vanadium and Hultgren balls does not, how-
ever, appreciably effect hardness number of
steels up to 700 Brinell.

DOUBLE CARBIDES. Double Carbides of
Iron and Chromium (Die Phasen "Fe₃C,
Cr₄C'' und Cr₁₀C₃Fe₃, die "physikalische
Rückstandsanalyse"), F. Sauerwald, H. Neu-
decker and J. Rudolph. Zeit. für anor-
ganische und allgemeime Chemie, vol. 161,
no. 2, Apr. 5, 1927, pp. 316-320. Authors
take view that if double carbides "Fe₃C,
Cr₄C'' really exists, it should be possible by
melting suitable mixture of iron, chromium
and carbon to obtain an alloy of correspond-
ing composition and this should show homo-
geneous microstructure; if alloy of this com-
position shows definitely duplex microstruc-
ture, it is strong evidence against existence
of carbide in question. See translated ab-
stract in Metallurgist (Supp. to Engineer),
May 27, 1927, p. 66.

IRON-COPPER. The Mixture of Molten
Iron-Copper Alloys (Ueber die Mischungs-
lücke in flüssigen Eisen-Kupfer-Legierungen),
A. Müller. Mitteilungen aus dem Kaiser-
Wilhelm-Institut für Eisenforschung zu Düs-
seldorf, vol. 9, no. 9, 1927, pp. 173-175, 12
figs. partly on supp. plates. Results of
tests on alloy of equal parts of iron and
copper show that in molten condition gap
or break exists in mixture with lower crit-
ical point at about 1500 deg. cent.

IRON-MANGANESE. Thermal Changes in
Iron-Manganese Alloys. Low in Carbon, R.
Hadfield. Roy. Soc.—Proc., vol. 115, no.
A770, June 1, 1927, pp. 120-132. As re-
sult of research author has found that low-
carbon alloys described, when heat treated
and quenched, do not possess remarkable
combination of tenacity and ductility dis-
played by manganese steel in anything like
same degree.

IRON AND STEEL

CORROSION. Report of Committee A-5
on Corrosion of Iron and Steel. Am. Soc.
Testing Matls.—Advance paper, no. 12, for
mtg. June 20-24, 1927, 72 pp., 22 figs. partly
on supp. plate. Report on inspection of
Fort Sheridan and Annapolis tests; specifi-
cations for zinc-coated products; zinc-coated
sheets; testing zinc-coated iron and steel
(galvanized) wire and wire products, iron or
steel telephone and telegraph line wires, iron
or steel tie wires, wire fencing, chain-link
fence fabric galvanized before weaving, chain-
link fence fabric galvanized after weaving;
methods of testing; field tests of metallic
coatings.

IMPURITIES, EFFECT OF. Influence of
Impurities on the Properties of Iron and
Steel, H. M. Boylston. Fuels & Furnaces,
vol. 5, no. 5, May 1927, pp. 569-576, 7 figs.
Influences of varying amounts of impurities
and addition of alloying elements on prop-
erties of iron and steel; effect of heat treat-
ment.

SILICIC ACID IN. The Determination of
Silicic Acid in Iron and Steel (Ueber die
Bestimmung der Kieselsäure in Eisen und

Stahl), P. Bardenheuer and P. Dickens.
Mitteilungen aus dem Kaiser-Wilhelm-In-
stitut für Eisenforschung zu Düsseldorf, vol.
9, no. 11, 1927, pp. 195-206, 5 figs. Dis-
cusses different methods of determination and
describes new apparatus.

IRON CASTINGS

DEFECTIVE. Defective Castings. Iron
& Steel Industry and Brit. Foundryman, vol.
1, no. 3, June 3, 1927, pp. 55-57 and 64,
10 figs. Account of some wasters, problem
which they present and remedies applied,
purely from practical point of view.

GAS HOLES. Absorbed Gases in Iron
and the Creation of Gas-Holes in Castings,
B. Hird. Foundry Trade Jl., vol. 35, no.
565, June 16, 1927, pp. 495-497, 3 figs. As
result of experiments and past experience
following conclusions are arrived at: sprigs,
chaplets, studs, etc., are always source of
danger; their contact with molten metal in
mold should be avoided wherever possible;
when chills, or metal inserts of any kind,
are used in molds in contact with molten
metal, vent holes should be put in them to
allow gases to escape; where chills are
brought up to high temperature in mold
they should be renewed at frequent inter-
vals; molds having inserts should be poured
with metal as dull as is consistent with type
of casting; amount of gas given off by
chills, etc., is largely influenced by temper-
ature to which they are raised by molten
metal in mold, before solidification takes
place; all cast metals give off gases when
liquid and during solidification until they
reach point well below dull red.

LARGE. The Manufacture of Large Cast-
ings (La Fabrication des Grosses pièces en
fonte), H. Fabre. Fonderie Moderne, vol.
21, May 25, 1927, pp. 125-131, 4 figs.
Deals with castings of large dimensions
which present difficulties in molding; ma-
terial employed, patternmaking, molding, de-
fects, etc.

IRON FOUNDING

SIXTEENTH CENTURY. The History of
Iron Founding in the Sixteenth Century (Zur
Geschichte der Eisengiesserei im 16. Jahr-
hundert), P. Martell. Giesserei, vol. 14, no.
23, June 4, 1927, pp. 370-373. Through in-
troduction of blast-furnace practice, which
began in France and Italy, greater develop-
ment of iron foundries was possible; review
of work by Italian, Vanuccio Biringuccio,
containing information on processes used in
middle ages for production of bronze cannon,
furnace plates, vessels, etc.

IRON, PIG

DEPHOSPHORIZATION. Practical Assays
on the Dephosphorization of Pig Iron (Saggi
pratici di defosforazione della ghisa), A.
Angiolani. Industria, vol. 41, no. 3, Feb.
15, 1927, pp. 59-62. Theoretical discussion
of chemistry and thermodynamics of dephos-
phorization by means of oxides of Ca, Mn
and Fe; also results of experiments made in
Italy to determine proportions required for
slag formation and treatment of iron.

SILICON IN. Critical Investigation of
Method of Determining Silicon in Pig Iron
and Steel (Kritische Untersuchung der Ver-
fahren zur Siliziumbestimmung in Roheisen

und Stahl), A. Stadeler. Stahl u. Eisen, vol. 47, no. 23, June 9, 1927, pp. 966-969. Discusses different methods of determining silicon, and critical investigations of processes on specimens of pig iron and steel of different kinds with silicon contents of 4 to less than .01 per cent; advantages and disadvantages of processes.

LABORATORIES

FOUNDRY. Laboratories and Works of Beecroft & Partners, Limited. Foundry Trade Jl., vol. 35, no. 565, June 16, 1927, pp. 503-504, 2 figs. Laboratories comprise balance and combustion room, which is equipped with gas-fired 4-tube carbon combustion furnace fitted with Huxley type of special muffle; reference is made to carbon train of this furnace as into this important modifications have been introduced by laboratory staff.

METALLURGICAL. The Metallurgical Laboratory at the Exposition of the Fiftieth Anniversary of the French Association for the Advancement of Science (Le Laboratoire de métallurgie à l'exposition du cinquantenaire de l'Association Francaise pour l'Avancement des Sciences) E. R. Simonnet, Revue de Metallurgie, vol. 24, no. 4, Apr. 1927, pp. 194-199, 2 figs. Deals with research in physics, metallography, radio-metallography, mechanical tests, thermal treatment, physico-chemical tests and new alloys.

LEAD ALLOYS

CABLE SHEATH. Fatigue Studies of Telephone Cable Sheath Alloys, J. R. Townsend. Am. Soc. Testing Matls.—advance paper, no. 39, for mtg., June 20-24, 1927 13 pp., 12 figs. Fatigue studies of lead sheath for telephone cables, development of two forms of simulated service test and fatigue machine designed to test lead and its alloys; special precautions necessary in carrying out fatigue tests on soft metals; fatigue failure of lead and lead-antimony alloys is by intergranular failure; in case of lead-antimony alloys repeated stress appears to reduce solid solubility of antimony in lead, producing widened grain boundary as viewed under microscope.

MALLEABLE CASTINGS

STANDARDIZATION. Standardization in Foundry Practice (Normungsarbeiten im Giessereiwesen). Giesserei-Zeitung, vol. 24, no. 12, June 15, 1927, pp. 341-342. Standardization of malleable castings.

MALLEABLE IRON

OIL-FIRED FURNACE FOR. Experiences with Oil-Fired Reverberatory Furnace in Malleable Casting (Betriebserfahrungen mit dem Oelflammofen in der Tempergiesserei), A. Zankl. Giesserei-Zeit., vol. 24, no. 2, Jan. 15, 1927, pp. 35-38. Design of furnace and its use as mixer; temperature of exhaust gases and additional air; use of furnace for melting; oil consumption and operating results; advantages of this type of furnace.

PROPERTIES. Malleable Iron (La Malléable), M. Leroyer. Fonderie Moderne, vol. 21, May 10, 1927, pp. 101-111, 6 figs. Historical review dealing with European and American malleable; constituents of alloys FeC; theory of graphitization; influence of elements; temperature and time on graphitization; action of CO_2 and of CO on graphitization.

MANGANESE STEEL

PROPERTIES. Facts and Principles Concerning Steel and Heat Treatment, H. B. Knowlton. Am. Soc. Steel Treating—Trans., vol. 12, no. 1, July 1927, pp. 106-125, 5 figs. Effects of manganese in simple steels and composition properties and uses of various types of manganese alloy steels; new charts showing physical properties of some of pearlitic manganese steels are presented; properties of high-manganese steels; effects of manganese in steel castings and properties of steels containing manganese in combination with other alloying elements.

METALLOGRAPHY

ETCHING. Report of Committee E-4 on Metallography. Am. Soc. for Testing Matls. —advance paper, no. 22, for mtg., June 20-24, 1927, 5 pp., 2 figs. Note on etching nickel silver; discussion by J. B. Johnson on Etching of Steels with Various reagents.

METALS

AIRPLANE. Metals in Trans-Atlantic Airplane Flights. Metal Industry (N. Y.), vol. 25, no. 6, June 1927, p. 243, 2 figs. Ryan plane is built largely of tubular steel, almost only metal part being propeller which is made of duralumin; aluminum alloys; copper; brass, aluminum bronze, and bronze in engine.

DEFORMATION RESISTANCE. Determination of Deformation Strength of Metals by Means of Impact Test (Die Ermittlung der Formänderungsfestigkeit von Metallen durch den Stauchversuch), E. Siebel and A. Pomp. Mitteilungen aus dem Kaiser-Wilhelm-Institut für Eisenforschung, zu Düsseldorf, vol. 9, no. 8, 1927, pp. 157-171, 25 figs. Field of application of tensile and impact test; defects of standard impact test; stress distribution and flow phenomena with standard impact and with cone-impact test; deformations in specimen; determination of coefficients of friction metallographic investigation.

EXPANSION AND SHRINKAGE. Dilatation and Shrinking of Metals (Dilatation et retrait des metaux), C. Moressee. Revue Universelle des Mines, vol. 14, no. 6, June 15, 1927, pp. 225-229. Investigation for purpose of finding mechanical explanation of expansion and to determine why it varies with different metals; concludes that coefficient of expansion varies with temperature; it depends only on melting temperature; all metals expand approximately 3 per cent linearly in passing from absolute zero to melting temperature.

IMPURITIES. The Effect of Impurities in Metals, C. J. Smithells. World Power, vol. 7, no. 40, 41 and 42, Apr., May and June, 1927, pp. 184-191, 233-240 and 308-314, 6 figs. Reviews existing stage of knowledge of effect of various types of impurity on structure; electrical and mechanical properties of metals and alloys; they are considered under headings of gases, non-metallic impurities, and metallic impurities.

MACHINE TOOLS. Selection of Materials. Times Trade & Eng. Supp., vol. 20, no. 463,

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Committee E-4 on
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Industry (N. Y.),
927, p. 243, 2 figs.
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ISTANCE. Determi-
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von Metallen durch
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Kaiser-Wilhelm-Insti-
zu Düsseldorf, vol.
-171, 25 figs. Field
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SHRINKAGE. Dila-
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Investigation for
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Effect of Impurities
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metallic impurities

Selection of Materials,
pp., vol. 20, no. 463,

May 21, 1927, p. 231. Deals with metals for beds, frames and columns; spindles and bearings; gears and chucks.

RECRYSTALLIZATION. The Determina-tion of Temperature at the Beginning of Re-crystallization (Zur Bestimmung der Tem-peratur des Beginns der Rekristalisation). W. Göttingen and G. Tammann. Zeit. Für Metallkunde, vol. 19, no. 5, May 1927, pp. 187-188. Angle of slip of polished metal surface deposited on another surface grows rapidly at a certain temperature; this tem-perature is that of beginning of recrystalli-zation; at elevated temperature a polished surface loses its high polish; temperature at which roughening of polished surface takes place is likewise beginning of recrystalliza-tion.

RESILIENCE. Recent Research on the Resilience of Metals at the Experimental In-stitute of the Italian State Railways (Le ultime ricerche sulla resilienza dei materiali metallici nell 'Istituto Sperimentale delle Ferrovie dello Stato), P. Forcella. Rivista Tecnica Della Ferrovie Italiane, vol. 31, nos. 1 and 2, Jan. 15 and Feb. 15, 1927, pp. 16-31 and 72-88, 16 figs. Results of series of tests of rails, hooks, etc., giving chem-ical composition, tensile strength and em-brittlement; metallographic studies with pho-tomicrographs.

ROLLING AND FORGING PROCESS. Tests on Rolling and Forging Process (Ver-suche zum Walz- und Schmiedevorgang), G. Sachs. Zeit. für Metallkunde, vol. 19, no. 5, May 1927, pp. 189-195, 21 figs. Roll-ing and forging tests show that for a com-prehension of formation phenomena tests must approximate practical stress conditions; tensile stresses occurring in rolling of sheet and profiles are due to irregular material dis-placements.

SEPARATION FROM GAS PHASE. Sep-aration of Metals from the Gas Phase (Afscheiding van metalen uit de gasphase), A. E. Van Arkel. Chemisch Weekblad, vol. 24, no. 8, Feb. 19, 1927, pp. 90-96. Metals of high melting point, of which easily dis-sociated volatile compounds are known, can be obtained in pure coherent form by heating filament of metal in atmosphere of vapor of compound; best results are obtained if com-pound be prepared in evacuated apparatus in which metal is to be deposited. See brief translated abstract in Brit. Chem. Abstracts, Apr. 1927, p. 325.

STEAM TURBINES. Materials Employed in Steam-Turbine Construction (Die Werk-stoffe im heutigen Dampfturbinenbau), A. Thum. Zeit. des Vereines Deutscher In-genieure, vol. 71, no. 22, May 28, 1927, pp. 753-763, 21 figs. Present aim in turbine construction; notched-bar effect in metals; fatigue failures; strength of materials at elevated temperatures; influence of manu-facture on strength properties; materials for lowest parts and for blaze.

TEMPERATURE, EFFECT OF. Joint Research Committee on Effect of Tempera-ture on the Properties of Metals. Am. Soc. Testing Matls.—Advance paper, no. 24, for mtg. June 20-24, 1927, 4 pp. Progress re-port to sponsor societies; future program.

VISCOSITY. The Viscosity of Molten Metal and Alloys (Ueber die innere Reibung geschmolzener Metalle und Legierungen), A.

Dienas and F. Sauerwald. Zeit. für anor-ganische und allgemeine Chemie, vol. 161, no. 1 and 2, Mar. 14, 1927, pp. 51-75, 9 figs. Measurement of viscosity of antimony, copper, lead and their alloy systems, copper antimony, copper-tin and lead-bismuth; com-paratively high value for copper was found and connection between molecular volume and viscosity was pointed out, viz., the smaller the molecular volume the greater the viscosity; influence of composition of alloys on viscosity.

WEAR TESTING. Wear Testing of Met-als, H. J. French. Am. Soc. Testing Matls. —Advance paper, no. 41, for mtg. June 20-24, 1927, 19 pp. 11 figs. Factors affecting wear of metals and difficulties encountered in making both laboratory and service wear tests; two testing machines used in study of wearing properties of metals employed for widely different purposes are described and attention is given in particular to initial surface condition and "filming" of metals in relation to procedure employed in making wear tests; summary of present status of wear testing of metals and results of ex-perimental work to show that reproducible results and information consistent with prac-tical experience can be secured in laboratory.

NICKEL ALLOYS

NEW SILVER. New Silver Alloys (Neu-silberlegierungen), C. Rothert and G. Dern. Zeit. für Metallkunde, vol. 19, no. 4, Apr. 1927, pp. 158-161, 10 figs. Influence of varying copper, nickel and zinc content es-pecially on color and strength properties; as relatively good alloy, one containing 62 per cent copper, 18 per cent nickel, and 20 per cent zinc, is recommended; heat treatment and recrystallization; best annealing tem-perature is found to be 800 to 850 deg. cent.

NON-FERROUS METALS

CORROSION. Report of Committee B-3 on Corrosion of Non-Ferrous Metals and Al-loys. Am. Soc. Testing Matls.—Advance paper, no. 19, for mtg., June 20-24, 1927, 18 pp. Total-immersion tests; spray cor-rosion test; accelerated-electrolytic test; atmospheric corrosion; liquid corrosion; gal-vanic and electrolytic action.

SPECIFICATIONS. Report of Committee B-2 on Non-Ferrous Metals and Alloys. Am. Soc. Testing Matls.—Advance paper, no. 18, for mtg. June 20-24, 1927, 44 pp. 5 figs. Proposed revisions of standards and tenta-tive standards; methods of analysis of light aluminum alloys; tentative specifications for copper tubing for refrigerators; brazing solder; yellow brass sand castings for gen-eral purposes; bronze castings in rough for locomotive wearing parts; car and tender journal bearings, lined; rolled zinc.

OPEN-HEARTH FURNACES

PROBLEMS. Discuss Open-Hearth Furnace Problems, C. W. Veach. Blast Furnace & Steel Plant, vol. 15, no. 6, June 1927, pp. 278-279. Problems discussed at semi-annual technical session of open-hearth superintend-ents; furnace roof and walls were subjects of particular interest.

REGENERATION. Open-Hearth Furnace Regenerators, F. H. Loftus. Iron Age, vol. 120, no. 1, July 7, 1927, pp. 10-12, 2 figs.

Elements of design for proper passages, heat absorption and strength; suggested type.

SUSPENDED FLAT ROOF. The Flat Suspended Open Hearth Roof, A. L. Foell. Iron & Steel Engr., vol. 4, no. 6, June 1927, pp. 241-244, 5 figs. Experiences of Donner Steel Co. with suspended type of roof.

WATER-COOLING. Use of Water Cooling in Open Hearth Furnaces, W. Trinks. Fuels & Furnaces, vol. 5, no. 5, May 1927, pp. 585-586. Water cooling devices; temperature gradient through walls.

OXYACETYLENE CUTTING

RISER REMOVAL FROM CASTINGS. Heavy Steel Riser Cutting. Acetylene Jl., vol. 28, no. 12, June 1927, pp. 561-562, 2 figs. Better steel castings can be made where oxyacetylene cutting torch is used for cutting risers.

OXYACETYLENE WELDING

APPLICATIONS. A Resume of the Fields of Application Oxy-Acetylene Welding and Cutting, D. S. Lloyd. University of Toronto Eng. Soc.—Trans., Apr. 1927, pp. 38-48, 11 figs. Describes only those applications of process which have been very successful in reducing cost in the commercial field; deals with production, construction, repair, etc.

IMPROVEMENTS IN. Technical and Economical Improvement in Autogenous Welding and Cutting Plants (Fragen der technischen und wirtschaftlichen Vervollkommnung der Autogenschweiss- und schneidanlagen), W. Reinacher. Autogene Metallbearbeitung, vol. 20, no. 8, Apr. 15, 1927, pp. 106-117, 9 figs. Reviews and projects progress in design of generators particularly carbide hoppers, welding and cutting torches, pressure regulating valves, added materials, processes, safety, etc.; experimental data on $O:C_2H_2$ relation, critical remarks on various patented devices and processes.

STEEL FURNITURE. Quality Steel Furniture Gas Welded. Acetylene Jl., vol. 28, no. 12, June 1927, pp. 554-557, 13 figs. Manufacturer of hospital equipment has developed welding as an essential process in production of strong and durable steel furniture.

PIPE, CAST-IRON

CENTRIFUGALLY CAST. A New Process for the Manufacture of Cast-Iron Pipes (Ein neues Verfahren zur Herstellung gusseiserner Röhren), M. von Anacker. Schweizerische Bauzeitung, vol. 89, no. 21, May 21, 1927, pp. 280-284, 5 figs. Improved centrifugal-casting method by F. Arens, former collaborator of de Lavaud; results of strength tests; one feature of process is that ingot mold never comes to complete stop.

PIPE, STEEL

WATER MAINS. Steel Water Pipes; Their Development and Use, C. B. Varty. S. African Instn. of Engrs.—Jl., vol. 25, no. 9, Apr. 1927, pp. 158-170, 4 figs. Deals with development of process of manufacture and comments on merits and demerits of steel mains for water purposes; deals with welding, rolling, casting, surface treatment, etc.

REFRACTORIES

ALKALIES, EFFECT OF. Effect on Refractories of Alkalies Used in Refining of Metals, G. S. Evans. Fuels & Furnaces, vol. 5, no. 6, June 1927, pp. 767-768 and 780, 3 figs. Discussion of present uses of sodium compounds in foundry industry which include refining molten iron from cupola in teapot reservoir ladle or forehearth, desulphurizing in crane ladle, as final slag in air furnace malleable practice, for fluxing brass in oil and gas fired furnaces and as cupola flux. Abstract of paper presented before Am. Refractories Inst.

RIVETS

HIGH-STRENGTH STEEL FOR. The Use of Special Materials of Superior Strength for Rivets of Steel Structures (Die Verwendung von höherwertigem Sondermaterial für die Nieten von Eisenbauten) Dörnen. Bauingenieur, vol. 8, no. 1, Jan. 1, 1927, pp. 2-4. Discusses tests made in 1922 to 1924 and points out advantages of using high-strength materials under proper conditions.

ROLLING MILLS

BEARINGS. Anti-Friction Bearings on Roll Necks of Rolling Mills, E. C. Gainsborg. Iron & Steel Engr., vol. 4, no. 6, June 1927, pp. 274-276. There are certain outstanding advantages that use of anti-friction bearings offer, which are not had in plain bearings; these are control of gage thickness, brought about because of close tolerance to which ball and roller bearings are manufactured; speed of operation can be increased without undue heating.

ELECTRIC MOTORS FOR. The Application of Synchronous Motors in Steel Mills, H. A. Winne. Iron & Steel Engr., vol. 4, no. 6, June 1927, pp. 250-256, 11 figs. Refers to motors furnishing power for machine, roll, and other drives.

MANNESMANN TUBE. Mannesmann Process (Das Schrägwalzen), F. Kochs. Stahl u. Eisen, vol. 47, no. 11, Mar. 17, 1927, pp. 433-446, 30 figs. Explains formation of central hole or fissure in billet or block as it passes through mill; author ascribes this to fact that certain stage in its passage through tapered skew rolls, block of steel assumes elliptical cross section, axis of ellipse rotating through steel as it is pushed forward and turned around by rolls; another feature is rotation of billet and twisting or torsion which it undergoes in consequence of fact that it is, at same time in contact with two rolls of widely varying diameters; experimental study of process made by arresting rolls as quickly as possible while billet is passing through them and thus obtaining specimen billets in various stages of operation. See also translated abstract in Metallurgist (supp. to Engineer), May 27, 1927, pp. 68-69.

MOTOR ROLLERS. Motor-Driven Table Rollers. Iron Age, vol. 119, no. 23, June 9, 1927, pp. 1663-1664, 1 fig. Unique design in which roller shell houses driving motor; variable speed may be had if required; motor roller is product of Schloemann Co., Düsseldorf; it has been in use in Germany for more than 2 years. See also description in Iron Trade Rev., vol. 80, no. 23, June 9, 1927, pp. 1470-1471 and 1477, 4 figs.

OF. Effect on Re-
[...]sed in Refining of
[...]els & Furnaces, vol.
[...]. 767-768 and 780.
[...]esent uses of sodium
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[...]m cupola in teapot
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[...]lls, E. C. Gainsborg.
[...]4, no. 6, June 1927.
[...]certain outstanding
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[...]tors in Steel Mills.
[...]Steel Engr., vol. 4,
[...]0-256, 11 figs. Re-
[...]power for machine.

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[...]oemann Co., Düssel-
[...]se in Germany for
[...]also description in
[...]0, no. 23, June 9.
[...]1477, 4 figs.

PLATE. Celebrates Its 137th Year by Installing New Four-High Plate Mill, E. C. Kreutzberg. Iron Trade Rev., vol. 80, no. 23, June 9, 1927, pp. 1475-1477, 2 figs. Lukens Steel Co. places in operation new 84-in. reversing plate mill at its plant at Coatesville, Pa. See also description in Blast Furnace & Steel Plant, vol. 15, no. 6, June 1927, pp. 280-281, 3 figs.

ROD MILLS. Heavy Rod Milling Machine. Iron Age, vol. 119, no. 23, June 9, 1927, p. 1671, 1 fig. Features of improved 58-in. unit include independent cross-rail down-feed brought out by Niles Tool Works Co.

ROLLER BEARINGS. Application of Tapered Roller Bearings on Roll Necks of Rolling Mills and Pinion Stands, F. Waldorf. Iron & Steel Engr., vol. 4, no. 6, June 1927, pp. 265-271, 8 figs. Results of tests on three-high 22-in. bar-mill roughing stand which is used to roll alloy steel; results show possibility of very considerable savings in power by use of roller bearings.

ROLLER BEARINGS. Bearings for Use in Rolling Mills, C. J. Klein. Iron & Steel Engr., vol. 4, no. 6, June 1927, pp. 271-274, 5 figs. Simplicity of design in mounting of roller bearings is worthy of note; diagrammatical sketches giving idea of different mountings of mill-roll bearings.

ROLLER BEARINGS. Factors Governing the Design of Roller Bearings for Roll Necks, F. H. Buhlman. Iron & Steel Engr., vol. 4, no. 6, June 1927, pp. 302-307, 3 figs. Design of bearing; computation of stresses acting on bearing.

ROUGH SHEET AND TIN ROLLS. Rough Sheet and Tin Mill Rolls, W. R. Kneeland. Iron Age, vol. 120, no. 1, July 7, 1927, p. 13. "Tuesday" roughness explained as due to "Crazing" of the roll's surface; cause and remedies.

SHEET MILL. Sheets Rolled to 16-Gage on Three-High Backup Mill, J. D. Knox. Iron Trade Rev., vol. 80, no. 26, June 30, 1927, pp. 1656-1659. Skew-type feed table and side guides enforce straight line movement to piece in transit between stands.

SOAKING PITS. Soaking Pits Built with Recuperators. Iron Age, vol. 119, no. 25, June 23, 1927, pp. 1811-1812. First unit with this construction operated at Buffalo Plant of Donner Steel Co. since February.

STRIP MILLS. Rolling Stripsheets on New Continuous Mill, J. D. Knox. Iron Trade Review, vol. 80, no. 20, May 19, 1927, pp. 1271-1275, 9 figs. Practice followed in manufacture of strip sheet by Columbia Steel Co.

WIRE-AND-ROD. Sparrows Point Wire and Rod Mill, G. A. Richardson. Iron Age, vol. 119, no. 18, May 5, 1927, pp. 1291-1297, 5 figs. Methods and equipments employed at mill of Maryland plant of Bethlehem Steel Co.; straight line layout 1525 ft. long provides continuous flow of materials; rod mill has 17 stands. See also description in Am. Metal Market, vol. 34, no. 118, June 1927, pp. 13 and 15-17, 8 figs.

ROLLS

THERMIT REPAIR WELDING. Repairing Mill Rolls with Thermit. Iron Trade Rev., vol. 80, no. 24, June 16, 1927, pp. 1536-1537, 3 figs. Easy method described for building up worn wabbler ends; how molds are made and placed.

SHEET METAL

GALVANIZED, BLISTERS IN. Cause of Blisters on Galvanized Sheets, L. B. Lindemuth. Min. & Met., vol. 8, no. 245, May 1927, pp. 225-226. Usual theories do not explain phenomena observed; mechanically held water suggested as cause; three remedies suggested to correct condition.

RESISTANCE DETERMINATION. Determination of the Resistance of Plates (Ueber die Widerstandsbestimmung von Blechen), G. Hauffe. Elektrotechnische Zeit., vol. 48, no. 4, Jan. 27, 1927, pp. 106-107. Error is introduced into determination of specific resistance of sheet metal by measuring resistance of sample strip, if latter is not accurately rectangular in form; author evolves formula for determining true specific resistance of trapezoidal strip; by employing this formula it is possible to obtain accurate results without first working strip into exact rectangular form.

STACKS

HEIGHT. Effect of Height of Stack on Furnace Operation, W. H. Mawhinney. Fuels & Furnaces, vol. 5, no. 5, May 1927, pp. 579-581, 3 figs. As height of stack is increased, furnace pressure varies rapidly with variations in fuel consumption and changes in furnace pressure are much greater.

STEAM PIPES

DESIGN. Modern Pipe-Work Design, G. H. Willett. Elec. Times, vol. 71, no. 1858, June 2, 1927, pp. 760-764, 13 figs. Deals with cast iron; steel castings; riveted pipes; welded tubes; weldless tubes; joints, welded-on and riveted-on flanges; welded joints; velocities; expansion; valves; drainage; insulation and corrosion.

STEEL

AIRCRAFT ENGINE CYLINDERS. Accidental Fractures of Crankshafts of Aircraft Engines and the Best Means of Preventing Them (Sulle fratture accidentali degli alberi a gomito di motori d' aviazione a sui mezzi migliori per prevenirle), G. Montelucci. Rivista Aeronautica, vol. 11, no. 12, Dec. 1926, pp. 47-60, 12 figs. Metallographic study of European and American cases; recommends purest possible nickel-chrome steel, cold working of metal, final heat treatment to be very precisely regulated, and judicious lightening of finished crankshaft.

DEFORMATION IN HEAT. Deformation of Different Alloy Steels in Heat (Die Formänderungsfähigkeit verschieden legierter Stähle in der Wärme), E. Houdremont and H. Kallen. Stahl u. Eisen, vol. 47, no. 20, May 19, 1927, pp. 826-830, 10 figs. Static and dynamic method for determining resistance of deformation influence of different alloying elements.

ENDURANCE. Development of Simplified Testing Method for Determination of Endurance of Steel at High Temperatures (Entwicklung eines abgekürzten Prüfverfahrens zur Ermittlung der Dauerstandfestigkeit von Stahl bei erhöhten Temperaturen), A. Pomp

and A. Dahmen. Mitteilungen aus dem Kaiser-Wilhelm-Institut für Eisenforschung zu Düsseldorf, vol. 9, no. 3, 1927, pp. 33-52, 37 figs. Review of investigation heretofore carried out which in authors' opinion give a confused idea of behavior of iron and other metal alloys at high temperatures; based on his own investigation, elongation phenomenon was followed; maximum load at which elongation ceases, is taken as true endurance; tests on copper at room temperature and test on steel at 300, 400 and 500 deg. cent. shows that process gives reproducible values; points out applicability of process to series of carbon steel and to boiler plate alloyed and unalloyed; influence of pretreatment on endurance at elevated temperature.

HARDENING POINT. Use of Pyrometer to Determine Hardening Point of Steel, A. F. Hanley. Am. Mach., vol. 66, no. 23, June 9, 1927, pp. 986-987, 1 fig. Method which may be employed to determine desired critical hardening temperature.

HYDROGEN REDUCTION. Influence of Silicon on Oxygen Determination in Hydrogen Stream (Der Einfluss des Siliziums auf d i e Sauerstoffbestimmung im Wasserstoffstrom), G. Thanheiser and C. A. Müller. Mitteilungen aus dem Kaiser-Wilhelm-Institut für Eisenforschung zu Düsseldorf, vol. 9, no. 12, 1927, pp. 211-213, 2 figs. Discusses present status of hydrogen-reduction process; carbon determinations in silicated steels; application of hydrogen and reduction process is limited to silicon-free steel with low carbon content.

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pieces, after experience had shown that
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otherwise experienced toolmakers were not
adequate; gas oven of pot type, with pot
removed, was found preferable to other
types; work was suspended at end of wire
in center of oven; oven was started at black
heat and temperature raised so gradually
that if any part of work was seen to be-
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mainder, it was considered to be proof of
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together with heat-regulating and recording
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point in heating; many chromium-nickel
steels, however, show considerable difference
between critical points and it is believed
that this fact is not generally considered;
by quenching piece of steel, in which there
is considerable difference between Ac and
Ar points, at temperature close to Ar point
rather than Ac point, advantages of lower
quenching temperature are gained; maxi-
mum hardness and tensile strength with
suitable elongation are obtained and it is
believed that less dimensional change takes
place and that hardening cracks may be
eliminated.

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forging, improper forging, or wrong heat
treatment; hardening treatment should fit
composition of steel and character of work
to be drilled.

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News of the Society

THE ANNUAL CONVENTION

EQUIPMENT worth more than $3,000,000 will be on exhibit the week of September 19, 1927, in Convention Hall, Detroit, during the Ninth Annual National Steel and Machine Tool Exposition sponsored by the American Society for Steel Treating.

Practically all available space in Convention Hall has been contracted for. As in previous years, the tendency of the exhibitors will be toward roominess, permitting a clear view of the exhibits from all angles without crowding. Convention Hall makes available some 93,000 square feet, and over 95 per cent of which have been reserved by over 275 exhibitors.

Never before has there been such a representative grouping and exhibition of industrial machinery and labor saving devices as will be on display in Convention Hall. It has been estimated that the cost of shipping and handling all of the materials which will be shown will exceed $600,000. The privilege of viewing such an array of modern equipment is open to all members of the four participating societies and their guests.

During the week of the exposition, the American Society for Steel Treating, the Institute of Metals, the Society of Automotive Engineers, and the American Welding Society will be holding technical sessions in Hotel Statler and the Book Cadillac. It is estimated that more than 25,000 metal experts from all over the world will be in Detroit during the week of September 19 with a total attendance of 80,000 to 100,000 persons.

The theater party, Tuesday evening; the grand ball, Wednesday evening; the annual banquet, Thursday evening, and the golf tournament are a few of the events which will make this convention a great success.

NATIONAL METAL WEEK

DURING National Metal Week to be held in Detroit the week of September 19, 1927, the Institute of Metals, the American Welding Society, the Society of Automotive Engineers and the American Society for Steel Treating will hold concurrently their annual or special meetings. At the same time the Ninth Annual National Steel and Machine Tool Exposition will be open in Convention Hall. The week of September 19, 1927, is destined to be an epoch making one in the metal and metal treating history. With these four major societies each holding their business and technical sessions, together with the largest educational industrial exposition ever held in the United States, an unparalleled opportunity is afforded thousands of persons to observe the production and manufacturing methods of America's leading industries.

In addition to the National Steel and Machine Tool Exposition with its myriad exhibitions and demonstrations of the latest developments in the metal working and metal treating field, a most interesting plant inspection program has been arranged for all members and guests.

The program provides for inspection during every afternoon of the week with the exception of Monday and an additional special trip is planned for Friday morning. The schedule of plant inspection is as follows:

TUESDAY AFTERNOON, SEPTEMBER 20

Cadillac Motor Car Co., Dodge Bros., Budd Wheel Co., Detroit Steel Products Co., Detroit Copper and Brass Rolling Mills.

WEDNESDAY AFTERNOON, SEPTEMBER 21

Lincoln Motor Co., Hudson Motor Car Co., General Motors Research Laboratories, Detroit Seamless Steel Tubes Co., Victor-Peninsular Co.

THURSDAY, AFTERNOON, SEPTEMBER 22

Ford Motor Co.—River Rouge Plant, Chevrolet Motor Co., Barnes-Gibson-Raymond, Inc., Fisher Body Corporation, Park Chemical Co.

FRIDAY MORNING, SEPTEMBER 23

Packard Motor Car Co., Ford Motor Co., Highland Park Plant, Parke-Davis Co., Michigan Malleable Iron Co.

FRIDAY AFTERNOON, SEPTEMBER 23

Ford Motor Co. at Fordson, Studebaker Corp., General Motors Plant. Grounds, Detroit Edison Co., Trenton Channel Plant.

DEFINITIONS OF TERMS RELATING TO HEAT TREATMENT OPERATIONS

(Especially as related to Ferrous Alloys)

THE Joint Committee on Heat Treating Definitions composed of representatives of the American Society for Testing Materials, Society of Automotive Engineers, and the American Society for Steel Treating has formulated a set of definitions of terms relating to heat treating operations, especially as related to ferrous alloys.

These definitions have been approved in tentative form by the three societies, and will remain in tentative form for at least one year, during which time suggestions and criticisms are invited so that the Joint Committee can perfect the definitions to such an extent that they will be applicable to all branches of the industry.

The personnel of the Joint Committee is as follows:

A. S. T. M. representatives:—John Howe Hall, H. M. Boylston, G. B. Waterhouse. S. A. E. representatives:—George L. Norris, Stanley P. Rockwell, John A. Mathews. A. S. S. T. representatives:—J. Fletcher Harper, W. J. Merten, Bradley Stoughton, J. Edward Donnellan, secretary.

FOREWORD

1. During recent years certain confusion has arisen in regard to the meaning of commonly used heat treating terms. For instance, in one locality

or trade, any operation of heating and cooling resulting in a softening of the material, is being called annealing, whereas in other places to ''anneal'' means not primarily ''to soften'' but to heat to above the critical temperature and cool very slowly. Similar confusion as to meaning and application exists in regard to other terms and as a result ''annealing'', ''tempering'', ''normalizing'', etc., are being used by different people, to mean widely different things.

2. In any attempt to accurately define the terms commonly used in connection with heat treatment, the first question to decide and the most important one is: do the terms relate to the heat treatment operation itself, or to the results obtained by the treatment? In other words, is the term indicative of the structure or the condition obtained, or of the operation performed?

3. After careful consideration, it appears most logical and most in keeping with present day usage to have the terms so defined that they shall mean definite operations and shall not be considered as referring to the resultant structures or general conditions.

4. By ''critical temperature range'', as used in the definitions, is meant the temperature range illustrated by the following diagrams, taken from Howe.
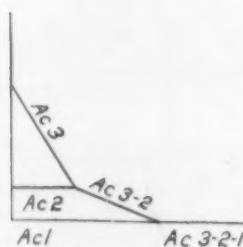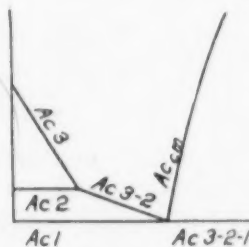

Fig. 1.   Fig. 2.

1. *Heat Treatment.*—An operation or combination of operations involving the heating and cooling of a metal or an alloy in the solid state.

> NOTE: This is for the purpose of obtaining certain desirable conditions or properties. Heating and cooling for the sole purpose of mechanical working are excluded from the meaning of this definition.

2. *Quenching.*—Immersing to cool.

> NOTE: Immersion may be in liquids, gases or solids.

3. *Hardening.*—Heating and quenching certain iron-base alloys from a temperature either within or above the critical temperature range.

4. *Annealing.*—Annealing is a heating and cooling operation of a material in the solid state.

> NOTE 1.—Annealing usually implies a relatively slow cooling.
> NOTE 2.—Annealing is a comprehensive term. The purpose of such a heat treatment may be:
> (a) To remove stresses.
> (b) To induce softness.
> (c) To alter ductility, toughness, electrical, magnetic or other physical properties.
> (d) To refine the crystalline structure.
> (e) To remove gases.

In annealing the temperature of the operation and the rate of cooling depend upon the material being heat treated and the *purpose* of the treatment.

Certain specific heat treatments coming under the comprehensive term "annealing" are:

    A. *Normalizing.*—Heating iron-base alloys above the critical temperature range followed by cooling to below that range in still air at ordinary temperature.

> NOTE: In the case of hypereutectoid steel, it is often desirable to heat above the Ac$_{cm}$ line, as shown in Fig. 2.

    B. *Spheroidizing.*—Prolonged heating of iron-base alloys at a temperature in the neighborhood of, but generally slightly below, the critical temperature range, usually followed by relatively slow cooling.

> NOTE 1.—In the case of small objects of high carbon steels, the spheroidizing result is achieved more rapidly by prolonged heating to temperatures alternately within and slightly below the critical temperature range.
> NOTE 2.—The object of this heat treatment is to produce a globular condition of the carbide.

    C. *Tempering (also termed Drawing).*—Reheating, after hardening to some temperature below the critical temperature range followed by any rate of cooling.

> NOTE 1.—Although the terms "tempering" and "drawing" are practically synonymous as used in commercial practice, the term "tempering" is preferred.
> NOTE 2.—Tempering, meaning the operation of hardening followed by reheating, is a usage which is illogical and confusing in the present state of the art of heat treating and should be discouraged.

    D. *Malleableizing.*—Malleableizing is a type of annealing operation with slow cooling whereby combined carbon in white cast iron is transformed to temper carbon and in some cases the carbon is entirely removed from the iron.

> NOTE.—Temper carbon is free carbon in the form of rounded nodules made up of an aggregate of minute crystals.

    E. *Graphitizing.*—Graphitizing is a type of annealing of cast iron whereby some or all of the combined carbon is transformed to free or uncombined carbon.

5. *Carburizing (Cementation).*—Adding carbon to iron-base alloys by heating the metal below its melting point in contact with carbonaceous material.

> NOTE.—The term "carbonizing" used in this sense is undesirable and its use should be discouraged.

6. *Case Hardening.*—Carburizing and subsequent hardening by suitable treatment, all or part of the surface portions of a piece of iron-base alloy.

    Case.—That portion of a carburized iron-base alloy article in which the carbon content has been substantially increased.

    Core.—That portion of a carburized iron-base alloy article in which the carbon content has not been substantially increased.

> NOTE.—The terms "case" and "core" refer to both case hardening and carburizing.

7. *Cyaniding.*—Surface hardening of an iron-base alloy article or portion of it by heating at a suitable temperature in contact with a cyanide salt, followed by quenching.

UNAUDITED PROFIT AND LOSS STATEMENT
AMERICAN SOCIETY *for* STEEL TREATING
For the period from January 1 to June 30, 1927

INCOME		
Gross Dues		$ 30,795.58
Transactions Advertising	$ 21,241.68	
Transactions Sales	650.75	
Transactions Subscriptions	1,089.18	22,981.61
Reprints		1,041.36
Bindery Account		655.65
Book Account		203.33
Pencil Account		22.75
Pins and Buttons		16.00
Miscellaneous Receipts		218.76
Data Sheets	1,515.98	
Data Sheet Binders	1,088.10	2,604.08
Discounts Received	279.77	
Interest	780.08	
H. M. Howe Medal Fund	61.98	1,121.83
Sustaining Exhibit Membership		5,600.00
TOTAL INCOME		**$ 65,260.95**

EXPENSE		
Local Chapters		$ 13,605.65
Sectional Meetings		1,139.27
Transactions		15,962.72
Reprints		1,338.07
Bindery		447.87
Index		875.01
Book Account		117.39
Library		64.42
Data Sheets		2,344.65
Data Sheet Binders		864.80
Discounts Allowed		303.13
Bank Exchange		.40
E. D. Campbell Memorial Lecture		2.30
General Expense		3,111.05
1926 Convention Expense		12.25
Collection and Legal Expense		217.50
Insurance		368.20
Secretary's Office		8,400.18
President's Office		434.98
Treasurer's Office		2,327.70
Directors' Expense		1,861.09
National Committees		2,607.01
TOTAL EXPENSE		**$ 56,405.64**
EXCESS INCOME OVER EXPENSE		**$ 8,855.31**

BALANCE SHEET
As of June 30, 1927

ASSETS		
Commercial Account		$ 15,945.62
Savings Accounts		28,925.58
Accounts Receivable		7,802.54
Accrued Interest		100.69
Investments		82,846.25
Office Furniture and Fixtures		2,083.24
Inventory		4,129.95
1927 Convention Prepaid Expenses		10,726.05
TOTAL ASSETS		**$152,559.92**

LIABILITIES, RESERVES AND SUPPLIES		
Accounts Payable		$ 1,948.01
1927 Convention Advance Receipts		28,575.31
Reserves		35,515.05
Surplus		
January 1, 1927	$ 77,538.33	
Plus		
Credit Balance from Surplus Adjustment Account..	126.47	
Collection on Bank Account	1.44	
Excess Income over Expense for the period from		
January 1 to March 31, 1927, per statement...	8,855.31	
Present Surplus		86,521.55
TOTAL LIABILITIES, RESERVES AND SURPLUS.		**$152,559.92**

News of the Chapters

STANDING OF THE CHAPTERS

DURING the month of June there was 149 new and reinstated members, while 59 were lost through arrears and 14 resignations and deaths, leaving a net gain for the month of 76 members. The total membership of the Society on July 1 was 4,797.

In the following tabulation there appears the relative membership standing of the 32 chapters and 3 groups of the society as of July 1, 1927.

GROUP I		GROUP II		GROUP III	
1. Detroit	486	1. Hartford	134	1. Los Angeles	80
2. Chicago	411	2. Milwaukee	127	2. Tri-City	79
3. Philadelphia	357	3. Lehigh Valley	126	3. New Haven	78
4. Pittsburgh	346	4. Dayton	117	4. Washington	69
5. Cleveland	327	5. Golden Gate	109	5. Southern Tier	68
6. New York	277	6. Canton-Mass.	105	6. Worcester	66
7. Boston	255	7. Cincinnati	97	7. Rockford	65
		8. Indianapolis	95	8. Toronto	61
		9. Syracuse	91	9. Rochester	59
		10. Montreal	90	10. Columbus	56
		11. St. Louis	84	11. Providence	54
		12. Buffalo	62	12. Schenectady	46
		13. North-West	54	13. Fort Wayne	43
				14. Springfield	32
				15. Notre Dame	21

GROUP I—Detroit had a net gain of 28 members last month due to the splendid work of E. O. Mann at the Chevrolet plant. It is quite possible that the Detroit chapter will be the first chapter in the Society to pass the 500 membership mark. Chicago and Philadelphia both had small gains while Pittsburgh held its own. Cleveland and New York suffered slight losses while Boston gained.

GROUP II—The first three chapters in this group suffered a loss of members each, while Dayton, with a net gain of 17, advanced from 5th to 4th place, displacing Golden Gate. Canton-Massillon now holds 6th place, having had a net increase of 15 members last month, which advanced it from position 10. The other chapters in the group remain in the same relative positions as last month.

GROUP III—The tie last month between Los Angeles and Tri City has been broken, and Los Angeles goes ahead with a net gain of 1, while Tri City holds its own at 79. New Haven, in position 3 with a net gain of 3, is right on the heels of Los Angeles and Tri City. Worcester, with a net gain of 6, advanced from 8th position to 6, displacing both Rockford and Toronto, and

breaking the tie existing between Toronto and Worcester. The new group at Columbus with a net gain of 8 and a total membership of 56, advanced from 11th to 10th place.

CINCINNATI CHAPTER

The Grand Annual Ball was held jointly with the Engineers Club of Cincinnati at the Pines Country Club, June 21, 1927. A number of methods for cooling those who thought they were hot were demonstrated; in some cases the cooling was so drastic as to break the member. An interesting display of various home made quenching solutions was in evidence. The composition of some of these mixtures was rather complex, but nevertheless they showed no evidence of corroding the container and seemed to be very effective in action. A fine dinner closed the meeting. Those who tasted the chicken enjoyed it very much.

The following officers were chosen at the Annual Election:

A. J. Lucas, Supt., The Cincinnati Gear Co., Chairman.

E. M. Wise, Metallurgist, The Wadsworth Watch Case Co., Vice-Chairman.

W. J. Lange, Metallurgist, Robert J. Anderson, Inc., Secretary-Treasurer.

Executive Committee:

Professor G. M. Enos, University of Cincinnati.

Professor Roy O. McDuffy, University of Cincinnati.

N. M. Salkover, Queen City Steel Treating Co.

J. Hunter Nead, The American Rolling Mill Co.

H. Stanley Binns, Cincinnati Milling Machine Co.

J. W. Bolton, Metallurgist for The Lunkenheimer Co., Cincinnati, gave a very informative talk on, "The Properties and Heat Treatment of Cast Iron." Mr. Bolton first pointed out the numerous factors determining the strength of the iron, the most important of these being the amount, form and distribution of the graphite, which, is turn, is largely determined by the composition and size of the casting. Photomicrographs were shown demonstrating the typical structures obtainable with cast irons of several types. Curves were shown correlating the hardness and the tensile strength of a large number of castings of wide range of composition and strength. The possibility of heat treating cast iron by heating above the critical and quenching was touched on and aroused considerable interest.

The audience left with the feeling that cast iron was an engineering material of real merit in which strengths of from 10,000 to 50,000 pounds per square inch could be obtained as desired if suitable care were used in the foundry.

Marcus Grossmann, metallurgical engineer for the Central Alloy Steel Corp., spoke before the Cincinnati Chapter on the evening of May 24. The subject of the talk was the "Heat Treatment of Alloy Steels including Stainless Steel."

Mr. Grossmann showed a number of slides demonstrating various failures; some due to heat treatment and a number due to improper handling or to the choice of improper material. The parts ranged in size from that of the ram of a forging hammer to that of a phonograph needle. Numerous photographs

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were shown of parts that caused trouble in machining. Each of these parts had been carefully studied and the cause of the difficulty determined and what is of more vital interest, the method of avoiding the trouble indicated.

The behaviour of the high chromium steels during heat treatment was analyzed, and their behavior was correlated with that of the straight carbon steels. The ternary system, iron-chromium-carbon, over the region of interest to the steel treater, was described and the remarkable changes produced by the addition of chromium to carbon steels were shown.

The meeting closed with a discussion of the application of high chromium steels to dies, with methods for protecting steel during hardening and with some of the factors influencing the propensity of steel to harden when quenched.   *E. M. Wise.*

CLEVELAND CHAPTER

The outing of Cleveland chapter A. S. S. T. held June 29 at Cedarhurst Country Club has been pronounced one of the most successful events which the chapter has staged. More than sixty-five members and guests turned out for the fun. Those who were unable to attend certainly missed a whale of a big time.

The winning baseball team headed by ''6-Home Run Gurney'' and with ''Strike 'em out Benninghoff'' pitching were awarded free dinner tickets. Professor Boylston acted as arbitrator and does not know yet why he was not thrown in the swimming pool.

Horse Shoe ''Aces'' Jackson and Kerslake, directed by ''Horse Shoe King Briggs,'' walked away from all comers.

In tennis, ''Champs'' Pulsifer and Adelson reigned supreme while Ed Donnellan ably managed the contests.

The 18-hole blind handicap golf match produced some good scores, ''Case Hardening'' Wake Bell getting low gross of 90 and Frank Gibbons nearest to blind net 76 with a 75 net and Ed. Goodaire second with 74. For the guests F. F. Griswold shot the low gross on the day with 82 while F. Lu Bahn won nearest net with 78.

The event produced a number of new monikers for well known members namely, ''No Putt Simpson'', ''One Putt Sykes'', ''Low Putt Kelly'' a ''Long Drive Atlas Bill White.''

Official photographer Bayless hopped from pillar to post shooting every everywhere, and had a hard time finding time to play his golf match. Th movies will be shown at one of the first fall meetings.

The water-dogs led by Sam Harris, Cooke, Morgan, Moeller, Fenner several of the other bathing beauties exhibited themselves both in and out the swimming pool.

Dinner was served in the Clubhouse at 7:00 p. m., after which the priz were awarded. A vote of appreciation was expressed for the excellent and cordial manner in which Mr. Hendrickson, club manager of Cedarhurst, and sports Director, Mr. Newton, conducted the event. Both responded with short talks and invited the chapter members back at any time.

Nearly $100.00 worth of prizes were awarded the ''lucky'' winners of the

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contests. The bulk of the prizes were donated by the following companies and the chapter takes this opportunity of thanking them for their generosity:

1. Atlas Steel Co.
2. W. S. Bidle Co.
3. Case Hardening Service Co.
4. Cleveland Twist Drill Co.
5. Ferry Cap and Set Screw Co.
6. J. W. Kelley Co.
7. Lakeside Steel Improvement Co.
8. Lamson and Sessions Co.
9. National Lamp Works of G. E.
10. Otis Steel Castings Co.
11. Thompson Products Co.

Each prize winner was called on for a speech by Chairman Harry Smith as they were awarded their prizes.

The Outing Committee was headed by Bill White, assisted by Ray Bayless, Harry Smith, Bill Sykes and Jim Ayling. They wish to thank the members of the chapter for the loyal support which put the outing over so effectively.

MONTREAL CHAPTER

The members and executives of the Montreal Chapter of the American Society for Steel Treating forgot for the evening of May 30 the cares of office, shop, foundry and laboratory and gathered in the Ladies Ordinary of the Windsor Hotel, Montreal, to celebrate with an executive dinner and smoker the culmination of the first year of the chapter's existence.

At the dinner preceding the meeting were present: C. F. Pascoe, Dr. A. Stansfield, Gordon Sproule, W. H. Eisenman, J. Fletcher Harper, A. W. J. Chacksfield, T. C. McConkey, W. J. Pead, F. P. Petzold, F. H. Williams, Robert Job, L. Lowry, A. Mathewson, and D. G. MacInnes. As the dinner was late in starting, there was little time to discuss any of the business of the chapter. Mr. Eisenman, secretary, and Mr. Harper, president of the national organization, announced that if it were agreeable the Society's semi-annual meeting would be held in Montreal next winter. Mr. Harper expressed the hope that it would be possible in the future for the parent organization to keep in closer touch with the branches to their mutual advantage.

The resolution was passed at the dinner that the national body be invited to hold the semi-annual meeting at Montreal, and Mr. Mathewson, secretary of the tourist bureau of the Montreal Board of Trade, who was present, pledged the support of his organization in assisting the convention.

The opening events of the smoker were the presentation of the secretary-treasurer's and chairman's report and the election of officers. The reports showed that the first year of the Montreal chapter had been a satisfactory one, with more than 90 paid up members, and with an average attendance of 60 members at the monthly meetings during the year. The class in metallurgy and steel treating had a registration of 60, and the average attendance at the lectures was 45.

The voting by ballot for the office of treasurer conceded that office to Gordon Sproule, lecturer at McGill University. Dr. Stansfield resigned the chair to C. R. Crook, secretary of the Canadian Railway Club, who read

the slate for the balance of the offices, and called for a single vote for their election.

The officers for the year 1927-28 are: Honorary chairman, Dr. Alfred Stansfield, head of the department of metallurgy, McGill University; chairman, C. F. Pascoe, metallurgist, Canadian Steel Foundries Ltd.; vice-chairman, Fred H. Williams, assistant test engineer, Canadian National Railways; secretary Duncan G. MacInnes, Quebec editor, Canadian Machinery; executive committee, Robert Job, vice-president, Milton Hersey Co.; Robert J. Noakes, superintendent, Canadian Pneumatic Tool Co.; W. J. Pead, engineer, Montreal Light Heat & Power Cons.; W. J. Hall, salesman, Lion Grinding Wheels Ltd.; W. M. Townsend, superintendent, Montreal Locomotive Works; H. S. Weldon, Dominion Textile Co.; T. C. McConkey, superintendent, B. J. Coghlin Co.; F. P. Petzold, Simonds Canada Saw Co.; A. W. J. Chacksfield, Norton Steel Co.; and R. K. Linagh, test engineer, Canadian Pacific Railway.

Following the election of officers Mr. Harper gave a short talk, and Mr. Eisenman entertained the audience with an account of their trip with Fred Williams and D. G. MacInnes to Brome Lake on Sunday, May 29.

At Brome Lake, he continued, the party went by row boat to the island estate of Mr. Williams, and found none other than Charles Pascoe, who was peacefully engaged in his avocation of fishing. Thanks to his skill the party had fish for lunch, the cooking of which was supervised by Sidney Williams, the competent son of the former secretary. When the food was ready for eating, however, the temptation was too great for the cook, and the speaker had to take hold and demonstrate the results of his good training at home.

A dramatic moment was provided during the evening when Mr. Eisenman, greeted like a long lost brother Lionel Marcotte, representative of the well known Canadian Club.

The entertainment of the evening was provided by Allen Murray, formerly of the Dumbells, with a company of four dancers, Germaine Daigenault, Margaret Braye, Eleanor Campbell, and Bernice Campbell, and A. E. Light of Light Engraving Co., Montreal, well known boxing referee, with a series of four boxing bouts.

Mr. Murray and his company proved their ability in 12 executed numbers, one of the finest being a concerted number in which he danced with each girl in turn a different step, ending with an Apache dance.

Mr. Light produced four boxing bouts that were lively enough to hold the interest of the audience at all times. Among the boxers appearing were a dominion champion, a provincial champion and the champion of Norway in their particular classes. The entertainment concluded with a relay bout in which three boxers took part, and the referee got most of the blows.

D. G. MacInnes

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